LIDAR SURVEY FOR ARCHAELOGICAL KNOWLEDGE. THE CASE OF "DOMUS OF SECTOR B" IN VENTIMIGLIA (ITALY)

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ABSTRACT:

Ventimiglia, the ancient *Albium Intemelium*, was the capital of *Liguri Intemeli* independent until the Roman conquest (180 years before Christ). Romans, changed name as *Albintimilium* that in the Middle Ages, became Ventimiglia.
The upper part of the plain was the site of ligurian *Albium Intemelium*, the lower next *Albintimilium castrum*, a strategic node of via *Iulia Augusta*. The fall of the Roman Empire and the barbarian invasions led the city to ruin.
In the second half of the nineteenth century, during the enlargement of modern city in the plain of Nervia the ruins of *Albintimilium*, cashed from the Middle Ages by a large sand dune, were discovered.
The documentation of the archaeological area (medium-large scale) and monuments (architectonical scale) since 1980 is carry out by topographic, photogrammetric and LIDAR techniques.
These methodology has been employed in order to better understand the old urban conformation of the site.
From 2007 under the coordination of the Center of Museum Planning of the Italian Ministry of Cultural Heritage, a requalification project was started with the objective of improving the connection between the different monuments of the archalelogical site.
According to the project aim the studies in the sector B has been started again. In this part the excavation works realized from N.Lamboglia in 1955 underline an interesting finding: the *Domus*.
In order to support the archaeological research a complete LIDAR survey of the *Domus* of Sector B has been realized.
The LIDAR survey, today extensively used in the archaeological survey, has been employed to create a 3D model of the *Domus* ant to achieve the plan and some sections.
For the *Domus* of sector B the data processing has been performed by Sirio, a software realized thanks to the cooperation between Politecnico di Torino spin-off SIR s.r.l. (Soluzioni Innovative per il Rilevamento) and the Geomatic research group of the same university.
With Sirio in the first steps of data processing is possible to register, filter and orient the point clouds, moreover the software allow to realize true orthophotos, solid images and 2D drawings (sections, plans, façade).

The paper show the result of the *Domus* LIDAR survey, in particular is focused on data processing and 2D drawing extraction necessary for the archaeological knowledge and documentation.

1. INTRODUCTION

In the last few years, a great deal of experiences have been gained on the use of LIDAR techniques, usually integrated by digital photogrammetry, in order to obtain 3D models of cultural heritage objects.
Ranging from small object to buildings, building complexes, historical centres, archaeological sites and natural landscape, the papers presented in many congresses and symposia have demonstrated the possibility of obtaining a complete answer to 3D knowledge and understanding using just these two innovative techniques.
It should however mentioned that no costs/benefits analysis have been performed to show the real applicability of the obtained results in practical works and few papers has considered that, in most cases, the final users usually require 2D graphical results such as plans and sections.
The setting up of plans and sections by using LIDAR data can be interpreted as a low level usage of them and the obtained results do not have the same quality as the ones obtained using traditional techniques.
In particular for the archaeological knowledge the 2D drawings are the basic support for the correct interpretations of the ancient ruins.
Traditional techniques (e.g. direct approaches using distance measurements or indirect approaches using reflector-less total stations) involve remarkable limitations for complex objects like the Domus of Sector B.

In these situations, a productive integration between traditional and more innovative techniques is advantageous. In the following sections, an application of a LIDAR survey, integrated by simplified photogrammetry survey is described.

2. THE ARCHAEOLOGICAL AREA OF ALBINTIMILIUM (ITALY)

Ventimiglia, the ancient *Albium Intemelium*, was the capital of *Liguri Intemeli* independent until the Roman conquest (180 years before Christ). Romans, changed name as *Albintimilium* that in the Middle Ages, became Ventimiglia.
The last reconstruction of the topography of Albintimilium (the ancient Ventimiglia) by Lamboglia dates back to 1974 (Lamboglia N., 1976), and reflects the final phase of city life, placed in the fourth century AD.
The contribution is the result of over thirty years of research and indicates the unsolved problems. In relation with the difficulties of access to the area, only little parts of sector B has been studied.
During the archaeologist researches was discovered that the B *Decumanus* was crossed by a new building (III-IV century), which blocks the path and alters the regularity. Probably these remakes also determine the transformation of the corner of the near *insula* which is bevelled, perhaps to facilitate the movement of carriages. Sector B is strategic for the definition of urban building phases. Other closures of *Cardini* and *Decumani* were found and triggered important changes in the urban setting.
Among the most interesting found, two fragments of walls: both are made entirely in lightweight material, brick and tuff and have a duct drawn in the walls, (cm 10x5). They result in a closed rectangular tank.
The interpretation of structures is extremely complex. Orientation and position of both the concrete fragments indicate that the two traits could be part of original one wall, and identify the function of channel and tiles. Probably, it was a channel of fluid discharge, also reflected by the target slope.
About the tiles, the location and distance to each other suggests listing of round beams, usually used by Romans.
These beams would be part of a loft, justifying the use of lightweight materials for the walls.
In order to better understand the morphology of this *Domus* a survey has been planned and realized by LIDAR and Photogrammetry methodologies.

Figure 1 The archaeological area of Albintimilium, in the circle the Domus of Sector B

3. LIDAR SURVEY OF THE DOMUS

3.1. Data Acquisition

A Riegl LMS Z-420 laser scanner (figure 2), a TOF instrument, was employed. Table 1 summarizes the main technical details of the used instrument.

Figure 2: The Riegl LMS Z-420 during the acquisitions

Measuring range	up to 350 m
Minimum range	2 m
Distance measurement accuracy	± 5 mm
Measurement rate	3000-9000 pts/sec
Vertical Scanning range	80°
Horizontal Scanning range	360°
Weight	14.5 Kg

Table 1. Key specifications of the *RIEGL LMS-Z420*

In order to obtain a good quality in the detail description, a scanning interval of 30 mgon was employed in all the scan positions. Four different scan positions were taken in the area (figure 3).
Moreover, in order to achieve more information on the area metric images were acquired using an high resolution digital calibrated camera (Nikon D1X, 18 MPixel, equipped with 24 mm lens) which was mounted onto the top of the LIDAR instrument.
During the laser scanner acquisition, several reflector markers (figure 4) were placed in the Domus.

Figure 3 The Domus of Sector B in Albintimilium

Figure 4: Position of reflector markers employed during the laser scanner survey

Figure 6 Coloured point cloud.

Their positions were chosen in order to guarantee a minimum number of common points (at least 5) for each adjacent scan-pair with a suitable localization and a good geometrical strength (locating them at different heights).
All the markers were measured by the total station and referred to the coordinate system defined at the beginning of the survey.

3.2. Data Processing

This part of the work has been performed using two different software: RiscanPro and Sir-IO.
The first one was used in order to orient relatively each scan position to the photographs acquiring during the data achievement (figure 5) .

Figure 5 Misalignment between the target on the scan and on the photo

As is shown in figure 5 there is a difference between the target position in the scan and in the photo. The process performed in RiscanPro (mounting) allow to correct the misalignment among the sensors (camera and LIDAR).
The second software (Sir-IO) which was recently realized thanks to the cooperation between the Politecnico di Torino spin-off SIR s.r.l and the Geomatics research group of the same University were used in order to realize all the other processing steps.
Using this Software, the point clouds were filtered through a median filter (Bornaz et al., 2001) for data noise reduction. Moreover in order to obtain coloured point clouds is possible to link the radiometric information derived from the photos, to each scan (figure 6).
The scanner yields a point cloud in the sensor coordinate system (x,y,z) for each position.

Once data sets of all the scan positions were oriented relative to each other (traditional registration); thanks to the reflector marker coordinates, an absolute orientation of all the scans was performed using the "laser triangulation algorithm" implemented in the Sir-IO software (figures 7-8).
The final result was a complete point cloud of the Domus in the local topographic system, achieving a σ_0= 1.10 cm with respect the final tolerance of the survey.

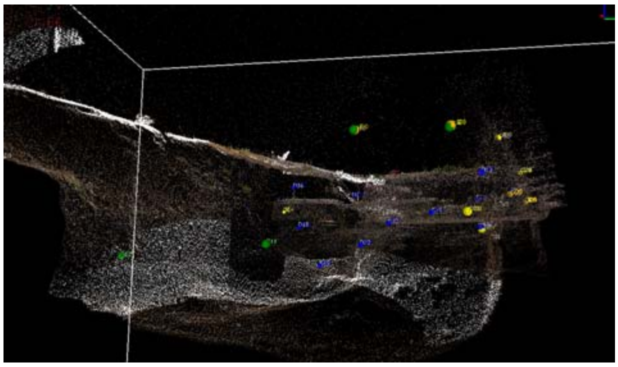


Figure 7 Point clouds during Laser triangulation in the Sir-IO Software.

Risultati triangol

Posizione/LST	Δx	Δy	Δz
LST / scan_1	-0.0117392	0.0034026	-0.000390266
LST / scan_6	0.00836844	0.000785533	-0.000436658
LST / scan_6	0.00374158	0.00829685	0.00148298
LST / scan_3	0.00811779	-0.00149313	0.013317

Figure 8 A part of the screen shot of the triangulation report

The oriented point cloud is only the first step of a LIDAR survey, it is very difficult to extract coherent information from millions of points.
The objective of the works were the creation of some sections of the Domus, a plan and a 3D model of the most interesting part (East wall) in order to give to the archaeologist some metric documents for improving the knowledge of the Domus.
For this reasons is necessary to extract suitable information from laser scanner data easier when no complete 3D model is

required. In the following parts are describes the extractions of metric informations from the complete point cloud.

4. 2D AND 3D METRIC PRODUCTS

In this part of the work different methodology were used in order to produce the final drawings, orthophotos and a 3D model of the East wall of the Domus.

4.1. Plan and section extractions

For the plan extraction the 3D point cloud has been used in order to extract the information for a correct representation of the Domus. Thanks to the tools implemented in Sir-IO that allow to export in .dxf stripes of the point clouds is easy to manage the geometry information and to achieve the final drawings. Moreover in order to better represent the real shape of the area some solid images were used to carry out the drawing "stone by stone" of the structures.
For the section extraction was followed the same methodology: extraction of stripes from the point cloud and integration in the drawing with the information derived from the solid images.
The following figures 9 and 10 shows the sections and plan extraction from the point cloud and the final plan of the area.

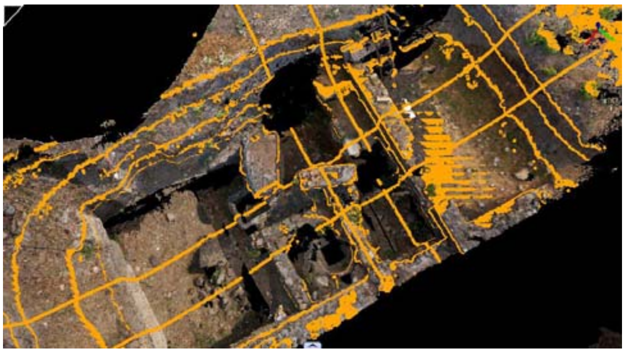


Figure 9 Plan and section extractions from the point cloud in Sir-IO

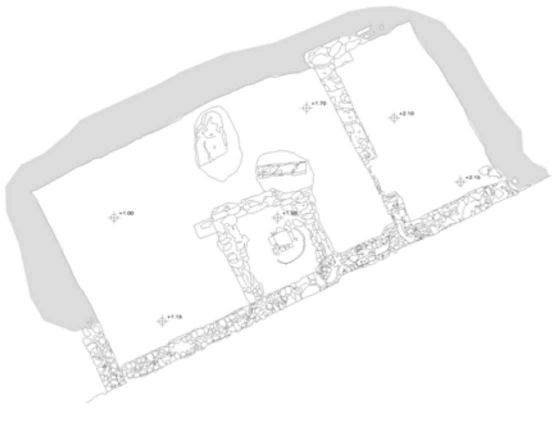


Figure 10 The plan of the Domus in Sector B 1:50 (not in scale)

4.2. Solid images

It is well known that from a point cloud it is very difficult to extract coherent information from, without a segmentation and a modeling phase. Different instruments were developed in order to make the use and the extraction of suitable information from laser scanner data easier when no complete 3D model is required.
One of the most useful product is represented by the solid image .
In Sir-IO software is possible to generate solid images that combine the 3D data of the LIDAR survey with radiometric information of photograps.
Furthermore, it is possible to survey the required details just by redrawing the contour of the objects on these products, as shown in figure 11.

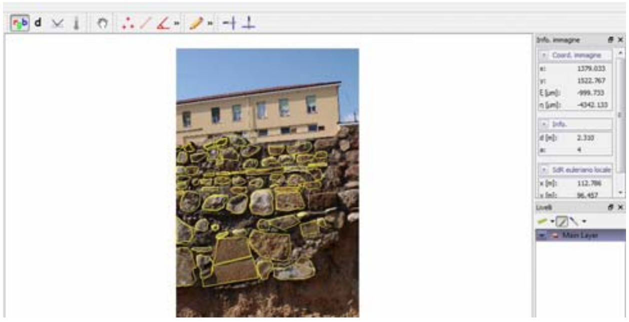


Figure 11 A screen shot of the plotting on the solid image generated in Sir-IO

With reference to the Domus, about 30 solid images were created in order to document all the surfaces of the object.
From these products, it was finally possible to draw the parts to be projected in the representation of the longitudinal and transversal sections.
The information obtained from the Sir-IO software, such as distances, angles (figure 12), point coordinates, and in particular the vector plotting, were finally exported in a CAD software in order to merge this information with the information achieved in the topographic survey in order to make the final correct drawings.

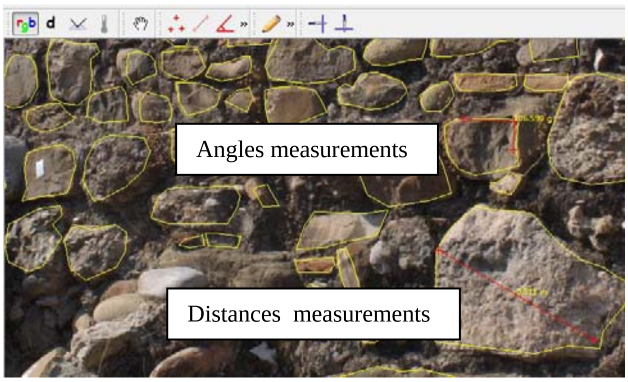


Figure 12 Distances and angles measurement in Sir-IO thanks to the solid images

The solid images were also suitable for the evaluation of the stratification of the walls, very interesting data's for the archaeological knowledge. This tool was used in order to create the sections of the Domus, in particular 3 sections were achieved. The integration between solid images and data extraction from the point clouds allow to generate a correct 2D drawing typically used for the archaeological documentation.
The following figure 13 shows the final results of a section.

Figure 13 Longitudinal section of the Domus 1:50 (not in scale)

4.3. Orthophotos

Another useful products that can be carried out in Sir-IO thanks to the DEM (Digital elevation model), derived from LIDAR data, and the photogrammetric oriented photos is represented by the orthophoto.
In the case of the Domus two orthophotos were achieved:
the orthophoto of the entire area (figue 14)and an orthophotho of the Est wall, integrated in the 2D drawing of the section (figure 15).

Figure 14 On the right the orthophoto of the Domus in Sector B scale 1:50 (not in scale)

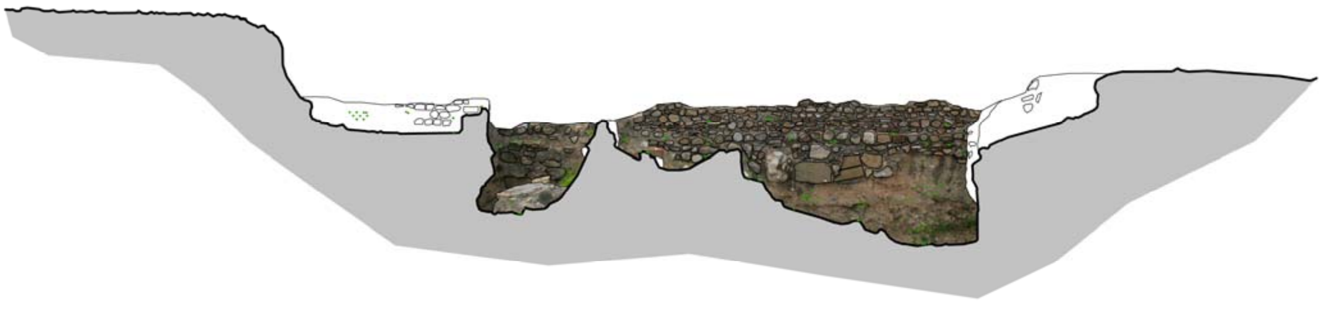
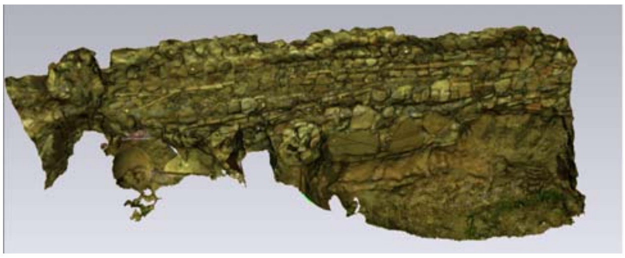


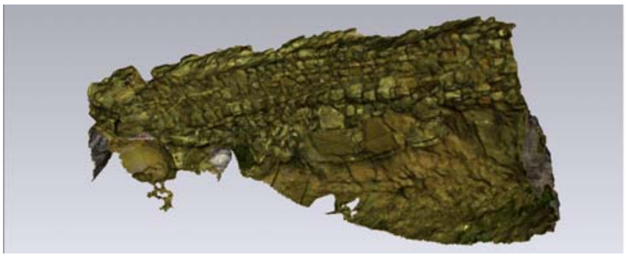
Figure 15 The orthophoto of the East wall integrated in the 2D section drawing 1:50 (not in scale)

4.4. 3D Model

From the point clouds of the area some test for realized 3D models were be performed in order to obtain some textured (Berladin J.A et al, 2002) views of the East wall.
This product is not important such 2D drawings and orthophotos for the archaeological knowledge but is an interesting instrument for realistic views and reconstruction hypothesis based on computer graphic techniques.

For the area of the Domus in Sector B the points were implemented in Raindrop Geomagic Studio 5 software.
After the polygon creation and decimation some editing on the mesh were be necessary in order to create a correct model.
Finally the 3D model was texturized.
The figures 16-17-18 shows the 3D models achieved.





Figures 16-17 Views of 3D textured model of the East wall

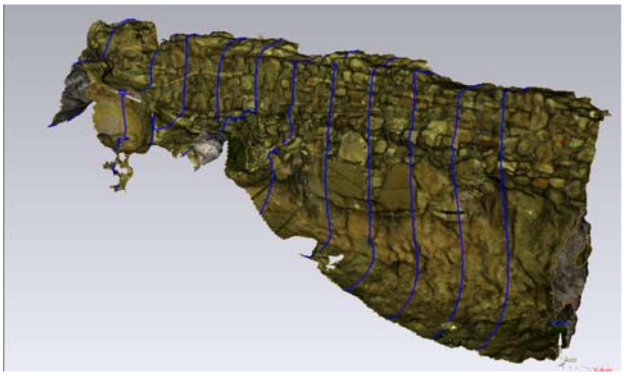


Figure 18. Section extraction from the 3D model.

5. CONCLUSIONS

In this paper is presented how LIDAR survey should be used in order to carry out suitable products for the archaeological knowledge.
The correct balance between different used approaches: digital photogrammetry and LIDAR (in the paper is skip the topographic survey description: networks etc..) is the correct way for a metric documentation of archaeological areas.
In the case of Domus in Sector B according to the complexity of the object a traditional survey, combined with a topographic survey doesn't allow to understand correctly the shape of the object, for this reason a LIDAR survey was planned and performed.
Moreover a complete model of the Domus (point clouds and 3D) represent an important archive that can be used for extract new sections, plans etc without a new survey on the terrain.
The LIDAR technique and digital photogrammetry, thanks to new management instruments (e.g. solid images), can also be used when 3D models are not the final products required by the end user.
The example described in the previous sections shows that a correct use of the LIDAR technique and of digital photogrammetry can speed up the acquisition phase and give all the information needed for a complete graphic representation of a surveyed object.

As interesting products for the Domus knowledge were achieved, according to the archaeologist a complete LIDAR survey of the *Insulae* will be realize in summer 2010 to achieve a complete archive of Sector B in Albintimilium.
This documentation will be fundamental because a requalification project that need to improve the connection between the different monuments of the archaeological area expect to start new excavation works in the Sector B.

6. REFERENCES

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