INTEGRATION OF LOW COST GEOMATIC TECNIQUES TO SUPPORT THE ARCHITECTONICAL PROJECT. THE PERLO CASTLE AREA SURVEY

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ABSTRACT:

In the high Tanaro Valley (Piedmont, Italy) the attestation of old pre-existence joined to the territory defence is possible to find numerous towers, castles, gouts and fortress.
Today the most part of these cultural heritage are in ruin.
Close to the municipality of Perlo few meters from the principal street, following a winding path is possible to arrive to a little hill; there the ruins of the old Castle of Perlo are hide from a rigorous vegetation.
The old might of the fortress is lost today, is like an explosion of stone fragments swallow from the natural environment. The walls cut in some cases the hillok and the old towers are like rock spur.
The requirement of the municipal administration to realize a preservation project for the historical area valorisation was the reason for begin complete survey of the Castle area.
The only available metric information's of the zone: the Piedmont Technical Cartography scale 1:10000 and the concerning aerial photograms, were not suitable in order to produce a project at an architectonical scale for the area.
For these reasons, a complete survey campaign of the hillok and the ruins was performed in order to obtain large scale maps and architectonical drawings of the ruins and the terrain morphology.
A traditional topographic approach with GPS and Total Station survey was followed for the hillok morphology definition.
For the other parts (tower and walls ruins) simplify photogrammetric techniques with the employed of an Unmanned Aerial Vehicle (mini-helicopter) were followed.
In particular the UAV was used in order to survey the towers, very high and not well measurable from the terrain.
The paper present the utilized techniques, the survey operations, the results and the problems during the data acquisition. All the operations were focused to give operative support to the architectonical planning of the area.
Finally the traditional graphic works (plans, façade and sections) and some example of 3D metrical views realized during the knowledge process for the Perlo castle are present.

1. INTRODUCTION

The digital documentation of cultural heritage monuments and sites is receiving great attention in the last decade and 3D modeling of objects or sites is one of the main research topics in this field.
In order to support the architectonical requalification project of Perlo castle area in this work a survey focused on low cost geomatic techniques and methodology for 3D graphic representation has been realized.
Nowadays the capability of close-range simplified photogrammetry software thanks to the considerable algorithm improvements and the automation in image-based modeling are a good way to obtain 3D surveys with excellent precision.
In this work a multi-scale approach has been performed, from the surrounding to the architectonical survey of the castle ruins.
Different geomatic techniques were employed; first of all in order to set up a common reference system GPS and Total Station networks has been achieved, moreover an integration of the previous techniques were employed in order to obtain a Digital Elevation Model of the hillock.
Afterwards for the architectonical survey a simplified photogrammetric approach were used.
As the elevation of the towers and the morphology of the terrain (wide slopes) didn't allow to acquire images that fully describes the towers; the photos for the photogrammetric process were acquired from a UAV mini-helicopter .
All the measurement were used to carry out final 2D and 3D graphics representation using CAD software and 3DS max for the photorealistic renders.In the following sections all the survey steps and methodology are described.

2. THE CASTLE OF PERLO (ITALY)

Close to the municipality of Perlo few meters from the principal street, following a winding path is possible to arrive to a little hillok; there the ruins of the old Castle of Perlo are hide from a rigorous vegetation.

Figure 1 The hillok in the Municipality of Perlo with the Castle ruins

From the historical analysis is not possible to date the exactly year of the Castle construction. The hypotesis made from the historian date in the Byzantine period the ruins of the ancient Castle.
The actual conformation of the Castle, limited to some ruins on a wooded hillock doesn't allow to analyze the architectonical and historical phases with precision.
Nevertheless is possible to certify a quadrangular tower in the upper side of the knoll.
This tower represent the oldest centre of the ancient lookout tower , positioned in the more dominant part of the hillock.
Moreover the tower materials and architecture are different from the others ruins.
On the top of the hillock some trace cover up from the ground with a regular series should represent the presence of the old transversal walls.
These elements are rest on a first surrounding wall on the high part of the area. Only few ruins in the South-West and North-East of the knoll are preserved.
In the lower parts of the hill two others surrounding walls are visible on the terrain, the first one very close to the previous (the oldest centre) and the second one in the first part of the hillock.
This pentagonal surrounding wall is join with the upper one due to transversal walls that climb up the knoll.
Of these old surrounding walls only some ruins are preserved, a part of about 50 m with a cylindrical tower in the north part is visible. Another part is observable in the south side with two others cylindrical towers the first one collapsed few years ago and the second one in good conditions (height of about 10 m).
In addition the trace of a fosse is well recognizable in the South part of the area . The fosse was used in the past in order to close off the area of the Castle from the other ridge.

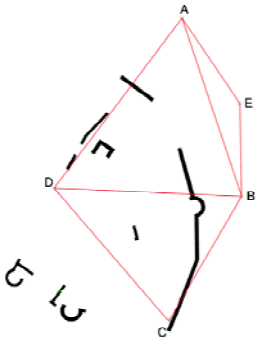
Figures 2-3 The Perlo castle ruins

3. THE SURVEY OF THE HILLOK

The only available metric information's of the zone: the Piedmont Technical Cartography scale 1:10000 and the concerning aerial photograms, were not suitable for a requalification project of the area. For these reason a survey of the area (hillok and Castle ruins) has been planned and done with topographic and simplified photogrammetric methodologies.

3.1. GPS network

In each metric survey, a first order network had to be fixed in order to define a local or global 3D coordinate system and to control the error propagations under the fixed tolerance .
For the area of Perlo the first order network has been realized with GPS.
According to the morphology of the area a network was made up of 5 control points (Figure 4).
Two Leica GPS System 500 double frequency (Figure 5) has been used: acquisition time of 45 minutes for each base and sample rate of 5 sec.



Figures 4-5 GPS network scheme (left) Leica GPS System 500 during the acquisition (right)

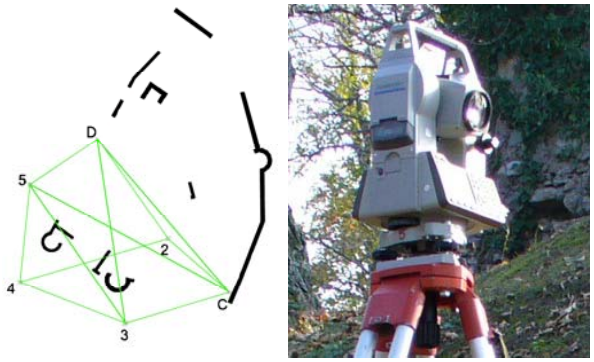
For a correct geo-referentation of the network a GPS permanent station (Mondovì) close to the area was used to carry out the coordinates of the points in UTM and Gauss-Boaga (Italian cartographic system) cartographic systems.
The coordinates of the vertexes were estimated with a least square adjustment (Starnet by Starplus Technologies); obtaining precisions that were suitable for the following field survey phase.
For the Geoid correction the Grid file of Geographic Italian Military Institute were employed.
The following table 1 shows the results after the a least square adjustment.

Vertex	σ_x [cm]	σ_y [cm]	σ_z [cm]
MONDO (GPS permanent station)	0.000	0.000	0.000
A	0.112	0.134	0.152
B	0.079	0.113	0.114
C	0.093	0.099	0.139
D	0.098	0.116	0.141
E	0.100	0.104	0.151

Table 1 1σ estimated values of the control point coordinates

3.2. Total station survey

In the west part of the hillok the thick vegetation didn't allow to use the GPS . In order to complete the network a Total Station (Sokkia Power Set 3000) was employed .
This second network was made up of 6 control points, the points C and D are the same of the GPS network (Figure 4).



Figures 6-7 Total station network scheme (left) Sokkia Power Set 3000 (right)

The survey was realized with a number of measured angles and distances that is exuberant with respect to the minimum geometric constraint in order to estimate the obtained precisions. As was done for the GPS network the coordinates of the control points were estimated with Starnet Software (for point C and D the coordinates derived from the GPS network were employed) . The results show (Table 2) the correspondence between the measurements and the statistical precision model. The achieved precisions are a lower order of magnitude than the tolerance required for the field survey.

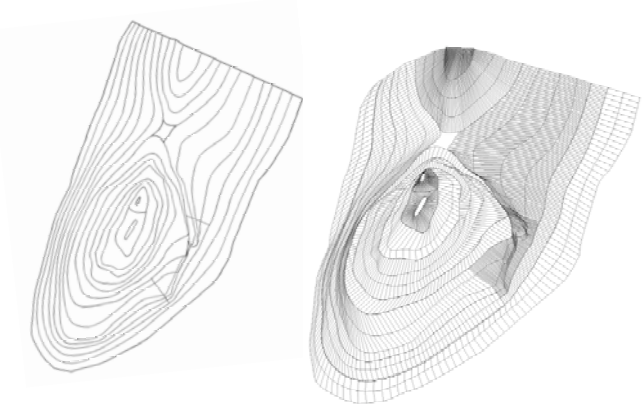
Vertex	σ_x [cm]	σ_y [cm]	σ_z [cm]
C	0.000	0.000	0.000
D	0.000	0.000	0.000
2	0.076	0.019	0.025
3	0.081	0.012	0.019
4	0.116	0.135	0.109
5	0.055	0.097	0.069

Table 2 1σ estimated values of the control point coordinates

3.3. Celerimetric survey

The objective of the work was a survey at 1:100 scale map and a 3D model of the area.

First of all, in order to realize a survey and a graphic representation of the hillok a model of the terrain is necessary to carry out the traditional countours and to achieve a 3D model.
In order to acquire the needed points a traditional survey was conduced using a total station (where the GPS signal was available a Real Time Kinematik survey were realized in order to integrate the celerimetric survey).
All the station points were located on the vertexes of the control network. A dense grid of points were measured and processed.
For the contours creation (equidistance 2m) and 3D modeling Arten and Autocad softwares were used.
The result are showed in figures 8-9.



Figures 8-9 Contours of the hillock (left) and 3d model (right)

Moreover a celerimetric survey of the architectonical ruins was realized in order to obtain the information for define the shape of the ruins and to achieve some points for the photogrammetric process (cap. 3.5).
In addition the surveyed points were integrated with direct measurements and interpreted in order to draw the required plans and sections.

3.4. UAV data acquisition

In the last years, new non-conventional aerial platforms have been developed for aerial photogrammetric surveys. This platforms, called UAV (Unmanned Aerial Vehicle) can be defined as: "aircrafts which are designed or modified, not to carry a human pilot and are operated through electronic input initiated by the flight controller or by an onboard autonomous flight management control system that does not require flight controller intervention"
In the case of Perlo castle area a modified version of the original mini-helicopter model, Voyager G8 RR (Figure 10), which was equipped with custom-made components in order to use it for photogrammetric purposes was used.
It is piloted by a human operator using radio remote controls, without any possibility to perform autonomous flights. So it can be more properly named RPV (Remote Piloted Vehicle). The mini-helicopter is equipped with a video-camera for navigation operations, a pressure altitude transducer and a custom-made remote-controlled mechanical system positioned in the lower part of the helicopter to carry a camera for image acquisition.
This mechanical system is able to rotate around two axes, so it is possible to orient the camera in different directions during the flight. In this work a Nikon Coolpix 8400 (8 MPixel resolution) camera was used for image acquisition (Figure 11).

Figures 10-11 The Voyager G8 RR mini-helicopter (left), the Nikon Coolpix 8400 set up on the mechanical system (right)

The digital camera is capable to perform remote controlled shoots.
During the flight of the mini-helicopter, it is possible to see the area which can be imaged and arrange the flight attitude in order to acquire the area to be surveyed.
This system was used in order to carry out a photogrammetrc simplified survey of the Castle towers.
The photogrammetric flight was planned to obtain photogrammetric images all around the towers.
A simplified photogrammetric program were used (PhotoModeler software by Eos system) in order to achieve a 3d survey and description of the castle ruins.
The following figure 12 shows the mini-helicopter during the acquisition and some used photos.

Figure 12 The mini-helicopter during the flight (left), some images acquired during the survey (right)

3.5. Simplified photogrammetric survey

For this part of the survey, a simplified photogrammetric software has been employed in order to obtain 2D drawings and 3D models of the towers.
This approach was preferred to a rigorous photogrammetric process or a LiDAR survey for budget and elaboration time reasons. Moreover the precision achieved with this methodology are suitable for the field survey.
The technique used in Photomodeler involves bundle adjustment process, which uses a calibrated camera to measure the ray paths from the principle point of the camera through the photographic image, to various points on the site.

Before the flight the camera was calibrated using iWitness (Photometrix) in order to estimate the camera internal parameters.
In order to obtain the exterior orientation with sufficient redundance, in every photo, at least six ground control points should appear, although this number depend of each photographs.
In the area of Perlo about 20 points for each photo, some measured target in the low part of the towers and some measured natural points easily recognizable in the photo were used in order to obtain the exterior orientation.
The images realized during the UAV flight were employed; for each tower at least 6 convergent images were used.
After the process describes below (typical multi-image photogrammetric process) a simplified 3D drawing (figure 13) has been achived in Photomodeler in order to obtain the basic geometry of the architectural ruins (discontinuity lines and 3 D points).

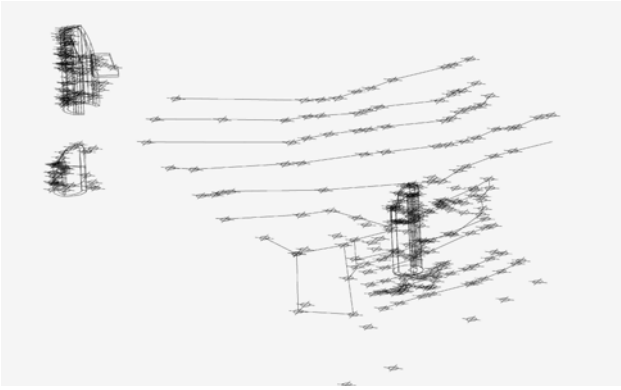


Figure 13 A simplified 3D drawing extract from Photomodeler

Moreover another interesting tool implemented in Photomodeler used in the project was the opportunity of texture generation of the architectural ruins.
This process was achieved in order to obtain correct textures of the towers for the modeling phase.
The figure 14 shows the obtained textures of two towers of Perlo castle area.

Figure 14 Textures realized in Photomodeler

Finally the points and lines generated in Photomodeler were exported in a more accurate 3D software and merged with the points measured during the topographic and GPS survey in order to obtain a complete graphic representation of the area (architectural ruins and hillock 3D models).
The following figures shows the finals drawings of the Perlo area Castle

Figure 15Plan of the Perlo Castle area scale 1:100 (not in scale)

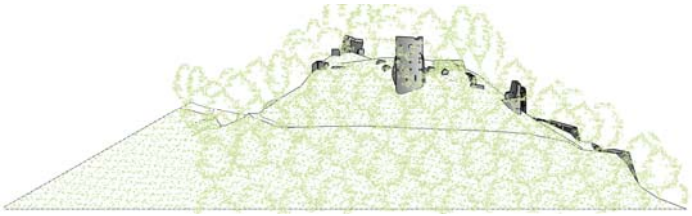


Figure 16 North view of the Castle scale 1:100 (not in scale)

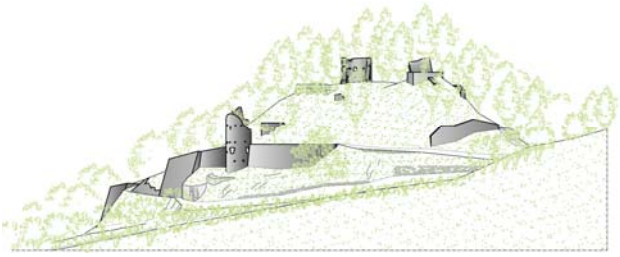


Figure 17 South view of the Castle scale 1:100 (not in scale)

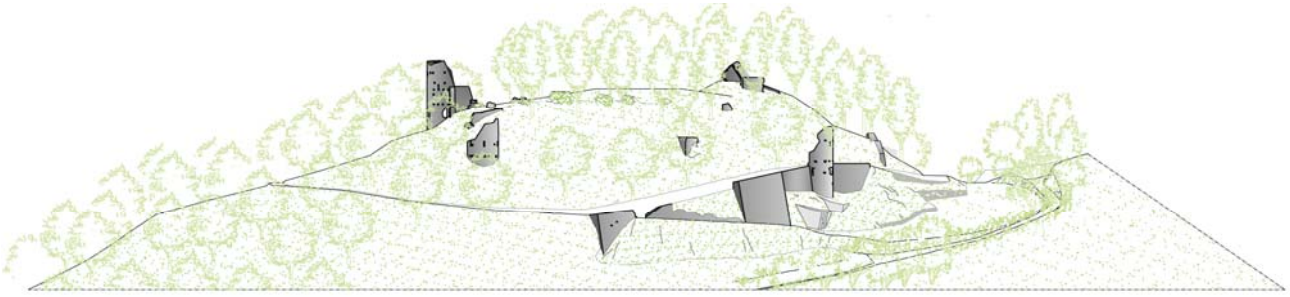


Figure 18 West view of the Castle scale 1:100 (not in scale)

4. 3D MODEL

Once a 3D survey is available, a polygonal model (mesh) is usually generated to produce the best digital representation of the surveyed object or scene. The photo-realism, defined as having no difference between a view rendered from the model and a photograph taken from the same viewpoint, is generally required and obtained with the texture mapping phase.

In the present work, from the final drawings realized using CAD software a 3D model of the area has been realized.

For the modelling 3DS max were employed in order to generate photo-realistic view of the hill and the castle. Only the ruins were textured using the data derived from the simplified photogrammetric process, for the knoll a uniform colour were employed. The following figures shows some views of the 3D model achieved.

Figures 19-20-21 3D model views of Perlo Castle area

5. CONCLUSIONS

During a requalification project the survey of the area is the first step of the knowledge.
Many times especially in marginal mountain areas where the graphical representation are not at large scale (> 1:500), is not possible to carry out a correct architectonical project.
In this paper is highlighted how through some low cost geomatic techniques is possible to generate the correct graphical support required from the designers.
The multiple geomatic methodologies applied were be tested in order to generate a typical 2D graphic representation and a 3D model of the area of Perlo Castle to supporting the architectonical project.
The aim of this work was the realization of a complete survey with low costs techniques.
The used techniques according with the demanded level of detail are suitable for producing drawing and 3D models for an architectonical project.
For the architectural survey (towers and walls) the image-based survey and modelling allows to perform 3D models at low cost while other techniques like laser scanner allows to perform more detailed 3D models with fast acquisition but with a lot of editing time and more costs.
Finally all the generated products were used for the project production of the area.
The following figures 22-23 shows the plan and a sections of the project.

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Figures 22-23 Plan and a section of the Perlo Castle area requalification project