

# AN INTEGRATED SURVEY FOR KNOWLEDGE AND PRESERVATION OF A CULTURAL HERITAGE: THE ALBANIAN FORTIFIED CITADEL OF ELBASAN

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## ABSTRACT:

The Inter-Link project “Progetto pilota per la conoscenza, conservazione e valorizzazione della Kalà (cittadella) di Elbasan – Albania”, relating to the 2004-2006 triennium and co-ordinated by Prof. Roberto Pierini, aims at the study of the Elbasan fortified citadel, the Kalà, in order to preserve, restore and exploit this all-important heritage of the city. The survey and rendering of archaeological, town planning and architectural attributes will be carried out by means of innovative methods and technologies, such as photogrammetry, laser scanning and georadar. Within the limits of this project, measuring and surveying campaigns have started in April, 2006, and final, full measurements campaign in February, 2007.

## 1. INTRODUCTION: METHODOLOGICAL AND TECHNICAL-OPERATING CHARACTERISTICS IN CULTURAL HERITAGE SURVEY.

Cultural heritage, particularly historical-architectural one, is rich in features related to the work's historic evolution and is often tightly bonded with the land, including not only the ground surface, but also the sum of environment- and human-related elements and of every feature related to the same geographical context.

Thus historical buildings show up as the result of a stratification of structural and functional changes, to be studied on the basis of completion time and procedures, in order to identify the most suitable strategies for their conservation and valorisation.

The effectiveness of protection, conservation and valorisation is based on a deep and detailed knowledge of the manufacture and its related context, to be centred on the georeferentiation (i.e. the attribution to each element of spatial coordinates relative to a known reference system) and the survey of the building.

The multidisciplinary of the study between humanistic and scientific-technological research sectors has in fact been the main goal of the Italian Inter-Link research project for years 2004-2006 titled ‘Progetto pilota per la conoscenza, conservazione e valorizzazione della Kalà di Elbasan – Albania’ (Pilot study for Albanian fortified citadel Kalà Elbasan's knowledge, preservation and development), coordinated by Prof. Roberto Pierini of Pisa University, in which both authors have taken part (inspection and first run of measurements in April, 2006 and final, full measurements campaign in February, 2007), contributing to the knowledge of this heritage in terms of position, shape, geometry and colour (georeferentiation and survey).

Current researches dealing with the Italian ‘Carta del rischio del patrimonio culturale’ (Cultural heritage risk map) show the urgency of the need to program cultural heritage conservation especially through damage prevention, so lending primary importance to the establishment of an informative system,

identifying the manufacture on a map and rendering it in a georeferred survey whose data base should be oriented to the protection, conservation and valorisation of architectural heritage and allowing for a rendering of the risks the work is facing and the environmental conditions potentially threatening its conservation.

In order to fully exploit this complex procedure it is necessary to reduce to a minimum the time to step from the ‘investigation’ (identification of the work, survey, georeferentiation and inclusion in the cartography) up to the ‘fruition’ of the information, so to avoid the paradox of using the system when the data it contains are outdated.

The aspect of data georeferentiation is thus crucial.

New surveying techniques, such as GPS, laser scanning, digital Photogrammetry and so on, meet all the requirements to make available, in the short term, a reliable and metrically correct basis, as well as rendering models enabling to match the cognitive exactitude of the metric survey with the need to provide an effective tool to both understand and communicate the site's values and meanings.

In fact, techniques and methodologies, typical of the geological-topographical-cartographical disciplines, are lately undergoing important innovations both for 3-D data collection and for the rendering process, featuring a strong trend towards digital technologies, thanks to the advances in electronics and information science.

Using up-to-date digital measuring technologies allows for new possibilities in the rendering of the collected metric data, no more limited to orthogonal projections, but also 3-D surface models, from which subsequent post-processing could generate solid models; these, in turn, would be the basis for the generation of contour line planimetry, sections, 3-D views, 3-D models with texturized surfaces, videos of the 3-d model obtained by the real-life object, each with a great impact for creating specialised documentation and extracting new information, as well as for widespread divulgation.

This provides new operating possibilities as well as new ways to face the many problems related to surveying and rendering in terms of accessibility, precision, logistics and operating procedures.

The different survey methods used in Elbasan, GPS, laser scanner, photogrammetry, have allowed for the creation of a 3-D model of the fortification which, in spite of its complexity, provides a starting point for the development of further processing.

This has allowed, for instance, to start up metrological, diagnostic and morphological studies and more generally to output specialized documentation and to extract new information and to process the collected data for divulgation and multimedia fruition.

Digital photogrammetric survey of the West side of the walls provides an example of how laser and photogrammetry can respond to the need of different experts to analyse the same work at different scales.

Laser scans have also allowed for effective, visually significant placing of the study subject as a whole in its urban context, and for rendering of the whole architectural unit. In fact, subsequent processing of point clouds have generated not only orthogonal projections, but also 3-D mesh models, polygonal models, contour lines cartography, outlines, sections, 3-D views, 3-D models with texturized surfaces and explorative videos of the 3-D model as surveyed.

Digital photoplans of details of relevant areas, and their rendering (at architecturally adequate scales) respond to the need to integrate the documentation with information related to greater scale renderings.

In any case, it must be pointed out that each and every measure is comparable with each other and referred to the global reference system of the digital model that, for this reason, takes on the function of 3-D geographical reference base and in turn stands as requirement for a true spatial information system for historic-architectural heritage.

## 2. THE SURVEY OBJECT – GOALS



Figure 1. View of the Elbasan fortress, highlighting the walls and the towers.

The fortified area currently features horseshoe-shaped outside walls, spaced by towers, for a total length of 600 meters (figure 1). It is fully accessible on its outer side although some trees, lining a pedestrian path, haven't allowed for an unimpeded sight of the walls, while its inner side is almost entirely dispersed in private properties and therefore practically inaccessible, save the West side, totally occupied by a recreational space attached to a restaurant whose owner has granted access to (and survey of) the walls and the interior of the towers (figure 2).



Figure 2. The survey area

### 2.1 The survey design

The approach to the survey of the fortification walls has had to deal with the peculiarities of this historical and architectural work which, unlike other protected cultural heritages, is currently used on a daily basis, subject to destination variations, restoration and maintenance operations, so that survey campaigns would not cover the huge amount of work required by the Kalà (as shown by the relevant diggings carried out on the West side of the walls between the first and the second campaign). In consequence, it has been decided to set up a survey design so that it could be developed and integrated by the personnel of the Tirane National Monument Institute (who also collaborated during the photogrammetric survey), Universities and public authorities.



Figure 3. GPS and traditional framing.

Survey design and management have been oriented to a rendering of the architectural complex in its whole, integrating it with details of particular value or meaning and allowing for future development and/or integrations. It has also been provided, as possible, for the obvious need for data georeferentiation as stated in the research project, and finally it should be the basis to provide support to Public Authority in the planning of restoration operations as well as to reorganize bibliographic, iconographic, historical and survey material.

The first step has involved a careful analysis of the available vector cartography for the city of Elbasan, which has shown to lack a definite reference: this has been georeferenced by means of GPS measures. An adequate location has been identified, expressly for the purpose, to set up a master GPS point, which has been materialised on the roof of the Elbasan town Hall. In order to define the coordinates of this point in the WGS84 reference system, a static survey has been carried out for about 48 hrs using the permanent GPS station of Orid (Macedonia), a node of the EUREF network, as a master station. This has also been exploited to define the position of landmark points, easily identifiable in maps, and to adequately distribute, around the walls, datum points which, after having been materialised and measured in RTK mode, have formed the vertices of the framing traverse for the following survey jobs (figure 3).

The framing traverse, formed by 17 vertices, runs along the accessible sections on both the outer and the inner side of the walls; related measures have covered all the necessary support points (totalling 290), identified by reflecting targets for photogrammetric and laser surveys.

Finally, one further relevant advantage due to the use of the absolute reference system is given by the ability to join different surveys without the need of sharing the same round-level traverse and referring to objects placed in distant spots.

## 2. 2 The photogrammetric survey

The photogrammetric survey has been carried out on a relevant wall section on the West side of the fortification, which, lacking the tree lining present along the South and East Sides, has allowed for clearer vision of different wall textures as well as of some historically and architecturally meaningful details.



Figure 5. The West survey area in 2007.

Photogrammetric takes for the generation of photoplans have been carried out using a Rollei Metric 6008 semimetric camera, with objective lenses with  $f=40\text{mm}$  and  $f=80\text{mm}$ .

Photoplans enable to transform the object's image (the photogram) from central projection to a metrically exact image, i.e. one lacking perspective distortions that take place during the shot (particularly those due to the non-normality of the shot), having the features of an orthogonal projection. The final product, in this case, is a 2-D, metric photographic document, projected on the average plane of the object, with a uniform scale which allows for correct reading and measuring of any of its features.

Photogrammetric survey has output a 1:50 photo mosaic of the West section of the walls.

Subsequent vector rendering of the photoplans, spatially rearranged in CAD environment, has allowed to highlight graphically many features, such as building techniques, wall deterioration, different materials used and their position in the wall, providing readily available support data for analysis and cataloguing of the work and for subsequent planning of diagnostic researches and conservation and maintenance operations.

The 2007 survey has covered a much wider area than the 2006 one, also including a relevant section of the west side walls, which have then been rendered based on the full photo plan (figure 5).

Finally, the photo plans have been composed in three dimensions, obtaining a model which has improved the spatial and dimensional perception of the object (figure 6).



Figure 5. Rendering of the photo plan (details).

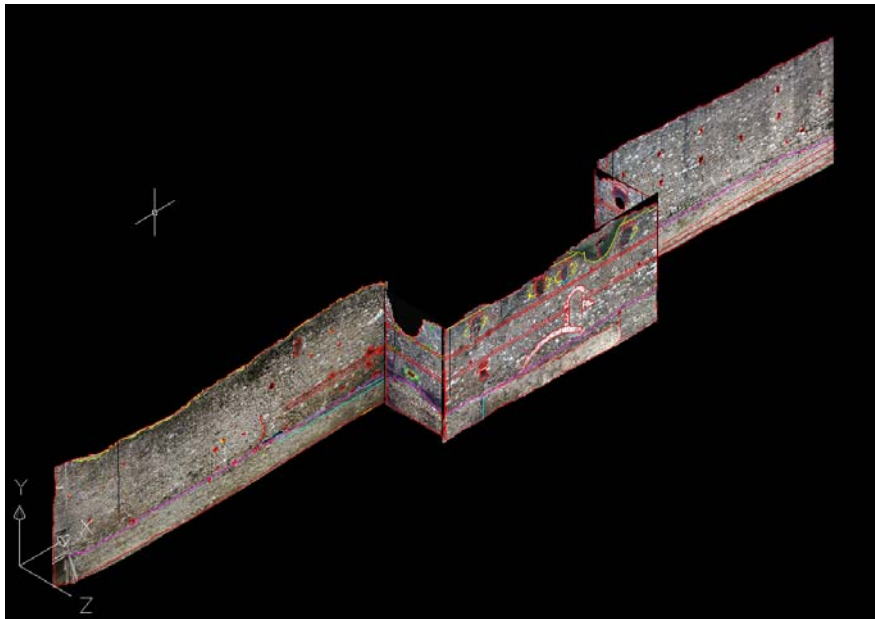


Figure 6. Photo plan in 3-D.

### 2. 3 The Laser Scanning survey

The complex has been scanned via the Riegl LMS-Z420i laser scanner, integrated with the calibrated Nikon D70s digital camera, at less than 40m from the walls. Thirty scans have been performed with an average resolution of 0.057 deg (equivalent to about 2cm on target) to scan in the entire external front, as well as the two towers and the interior of the walls in the West side, for a total of 100.000.000 points (figure 7).

Knowing beforehand the internal camera calibration and of its position relative to the scanner, the achievable images are already oriented in the reference system of each scan, and, these being georeferentiated in the project's topographical global reference system, the images also will be oriented in the project reference system.



Figure 7. Laser scanning surveys.

Treatment and processing of the relevant amount of raw data have been carried out by the authors and the CED technical staff.

Processing of topographical data has allowed for the merging of the laser-scanned point clouds in a single reference system,

generating the information-rich, highly complex 3-D digital model of the Kalà, which has then been queried for metrology, morphology and colour. Exploitation perspectives for this product are quite high: it can be noted that, while the surveying phase has been comparably short (7 days total), rendering is currently being carried out.

	Scan positions	Points number	Photos number	Data dimension
<i>West side (inside wall's)</i>	3	16.946.744	25	720 MB
<i>West side (outside wall's)</i>	9	39.026.630	70	1859 MB
<i>South side</i>	9	23.933.640	65	2430 MB
<i>South tower</i>	3	12.418.904	30	2649 MB
<i>West tower</i>	3	9.381.692	24	1260 MB
<b>TOTAL</b>	<b>27</b>	<b>101.707.610</b>	<b>214</b>	<b>8918 MB</b>

Table 1. Database properties.

Laser scans have been set up in order to collect the maximum amount of data available during the survey operations, with rather small point resolution on the object and rather wide field angles.

Raw laser scanned data not directly related to the Kalà have so firstly been filtered out.

Filtered data, rather than just trashed, are placed in their own layers, in order to view just the relevant sections of the wall structure (figure 8).

However, the ability to process original point clouds, which files are kept, to query new features of the structure itself or of the surroundings is still a strong point held by laser scanning.

Rendering operations can be performed, to a certain extent, on point clouds which have been colored via the oriented photograms shot with a digital camera.

Subsequently, significant polylines, sections and outlines which have allowed for accurate readings of trends of the wall faces, its different heights, pavement levels, tower morphology and structure, wall thickness, joints between adjacent sections and so on.

Besides, these intermediate products allow for sectioning the model along any given plane or sheaf of parallel planes, as well as along planes orthogonal to a given curvilinear path (figure 9)

A 3-D section model, lighter and easier to explore (in three dimensions), is then obtained. Sections can in turn be exported

in vector formats for further investigations in familiar CAD environments (figure 10).

Investigations by more strictly laser-related tools enable querying of the model for coordinates, distances, areas, volumes, etc (figure 11).

Point clouds have been processed for the reduction of the number of points, in order to allow for an exact reading of data and the subsequent generation of an easily manageable surface(mesh)-based 3-D digital model, which retains good functionalities, usability and versatility both for exploration and rendering purposes.

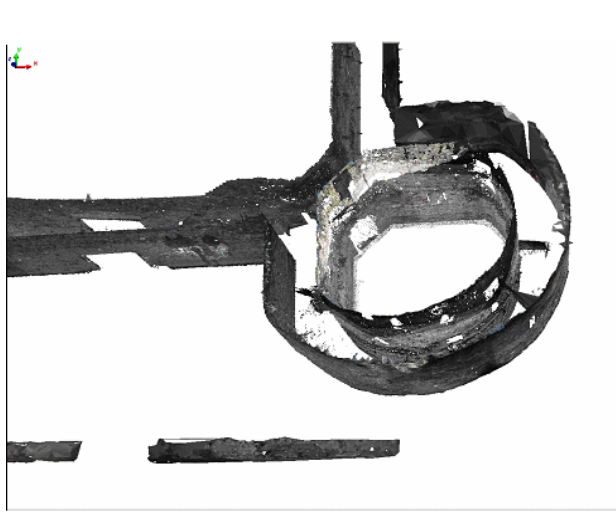


Figure 8. Points cloud filtered – 3-D view.

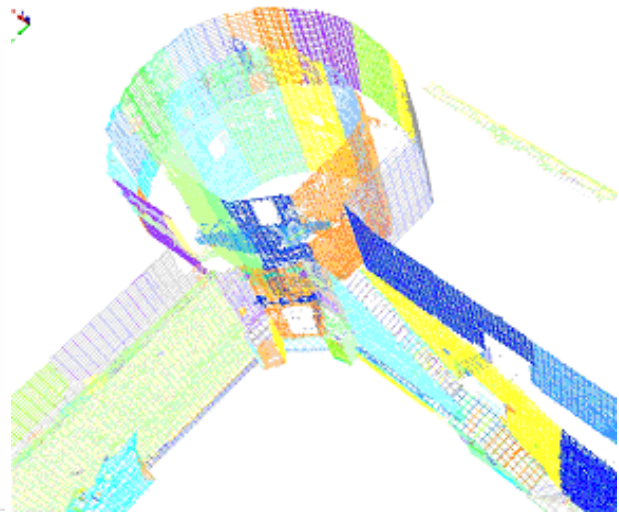


Figure 9. Sections from points cloud – 3-D view

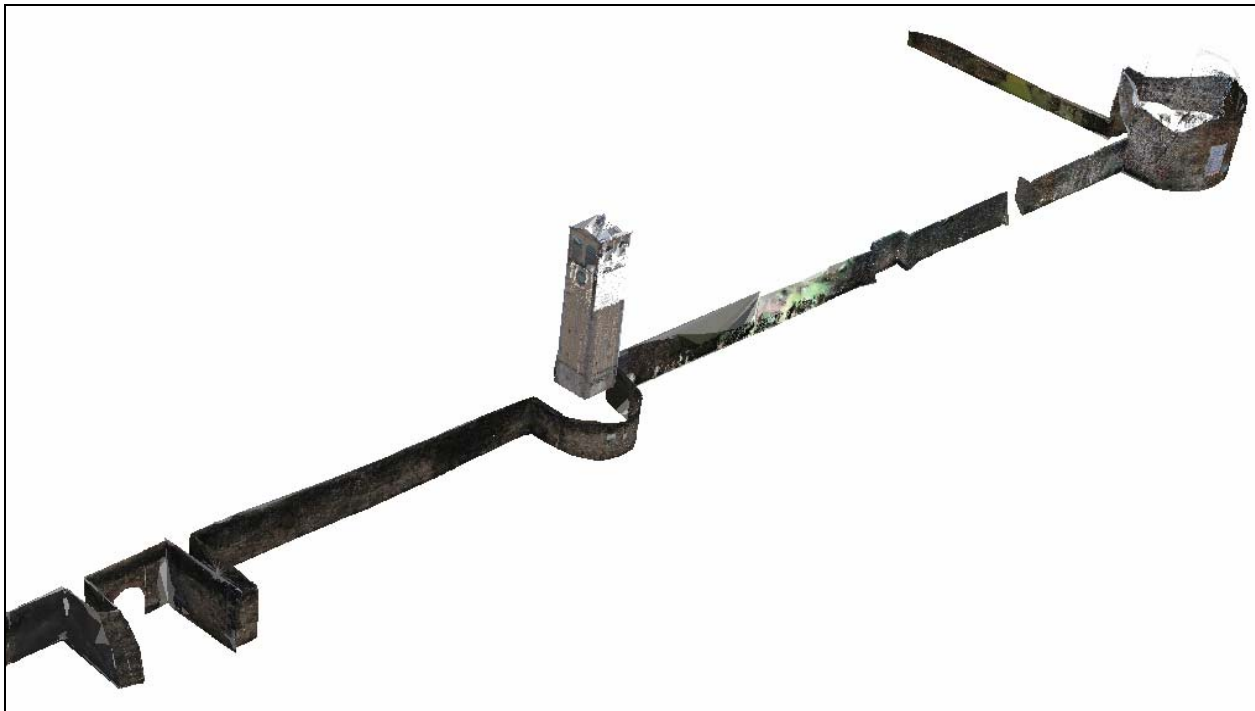


Figure 10. Walls South side points cloud – 3-D view.

This intermediate product has been coloured via the georeferenced digital images acquired by the scanner-mounted digital camera (texture mapping), and a movie covering all the Kalà both on its inside and outside has been generated.

Finally, orthophotos have been generated starting from laser scanned data of some parts of the model.

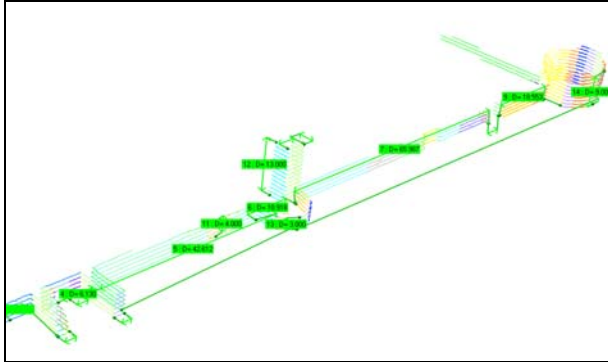


Figure 11. Walls South side measure on 3-D model.

### 3. CONCLUSIONS

New technologies provide the ability to survey a work with very low time requirements and high degrees of detail and precision.

The quality of modern instrumentation, their integration capabilities, the operating flexibility they allow as well as their ability to provide the basis for dedicated information systems merge with the output potentialities of modern rendering techniques. From a technical point of view, there currently are the conditions for exact surveys to become routine in the cultural heritage field.

The different survey methods used in Elbasan have allowed for the creation of a 3-D model of the fortification which, in spite of its complexity, provides a starting point for the development of further processing.

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Figure 12. Surveying team.