THE CASTLE OF GRAINES: DIFFERENT SURVEY METHODOLOGIES FOR THE DOCUMENTATION OF HISTORICAL BUILDINGS

E. Agosto (*), P. Ardissone (*), L. Bornaz(*)
(*) Politecnico di Torino – Dipartimento Ambiente, Territorio e Geotecnologie
Corso Duca degli Abruzzi, 24 – 10129 Torino – Italy
Tel. +39-011.564.7719/7687
Email: eros.agosto@polito.it, , leandro.bornaz@polito.it paolo.ardissone@polito.it

KEY WORDS: Terrestrial Laser scanner, Photogrammetry, Orthophotos, Archaeology.

ABSTRACT

The castle of Graines, near Brusson in the Aosta Valley (northern region of Italy), overlooks the whole Ayas Valley. This site played an important role in the history of the Middle Ages and it seems to have undergone few changes over the centuries. A complete archaeological analysis of the walls would lead to important results, not only from the archaeological research point of view, but also for the tourist valorisation of the site. Inside the European INTERREG IIIB project "Roman routes in the Mediterranean", coordinated by the Cultural Heritage Safeguard Office of the Aosta Valley, a high scale survey of a part of the boundary wall ,which is particularly interesting from an archaeological point of view, was carried out. The goal of this task had been to take advantage of a multidisciplinary project for a comparison of the new survey methodologies for the documentation of a historical building.
The cultural Heritage documentation today can receive an important aid from 3D models and from orthophotos of objects. Digital photogrammetry and LIDAR techniques speed up the creation of final metric supports. Different survey products have been obtained ranging from 3D and photogrammetric models, to ortophotos, and "solid images".
The real goal of this test was to evaluate from the users' point of view (in this case archaeologists) the different survey products that are now available, considering the user's needs and to point out the times, costs and specific skills that are required for each methodology.

1. INTRODUCTION

The European INTERREG IIIB project "Roman routes in the Mediterranean" has involved fifteen European Regions. The aim of this project was to create a network of several pilot plans on the safeguarding and valorisation of a common historical heritage: the Roman road system. The Cultural and Archaeological Heritage Safeguard Office of the Aosta Valley coordinated six different research groups, each with specific skills: classical archaeologists, Middle Ages archaeologists, historians and geologists. Each group carried out studies and analysis using different approaches and various techniques. The study area was the Ayas Valley and the specific historic topic was the transformation process that the Roman Road System has undergone between Roman times and the Middle Ages. The guidelines of the European project require particular attention to be paid to the spread of the results of all researches. All the involved research groups carried out studies, surveys and specialized analysis. All the data collected was organised in a GIS, designed for the correct registration, maintenance, consultation and updating of the data. One kind of data that was stored in the tool was high scale surveys: they were located by a medium scale cartography (1:10.000). In this way it was possible to obtain an overview of the whole area, from which users can access detailed survey data of a specific site using hyperlinks (fig. 1).
The geomatics research group of the DITAG Department of the Politecnico di Torino, in collaboration with the CeST-Marcovaldo (Centre for the Cultural Research on the Territory) carried out a survey on the medieval castle of Graines.
The main goals of this survey were:
1) to test different survey techniques, focusing on users' needs and requirements, in this case the users were the archaeologists;
2) to evaluate the different survey products now available, considering the accuracy, time, costs and specific skills required by each methodology;

Figure 1. Graines castle in the archaeological census GIS, and the hyperlink to the survey.

Figure 2. Details of the southern wall

3) to suggest an integration of the different survey products for the correct documentation of a historical building.

The castle of Graines was chosen as a test set because it is a very interesting site, from an archaeological point of view. It overlooks an important area rich in natural resources, and in the past it controlled many mountain passes and several lines of communication with the neighbouring valleys. The castle of Graines has not undergone any particular readjustment over the centuries. An accurate archaeological analysis of the boundary wall of the castle could lead to important results, not only for the archaeological research, but also for the tourist valorisation of the site. In fact the castle of Graines could be an important tourist resource for the Ayas valley.

Although little information about the castle coming from the documentary resources can be obtained, a preliminary survey of the structures of the building shows that the boundary walls were reinforced at different times(Fig. 2). This means that the castle had different phases in its history. In this case the goal of an archaeological analysis is to define the chronological sequence of the changes that the building has undergone. To improve the historical knowledge about the development of a building and to better understand the deterioration problems, archaeologists usually suggest carrying out a stratigraphic analysis of the walls. This is based on three phases: identifying and surveying the individual stratigraphical units; a short description of the characteristics of each unit; defining the temporal relationship between each stratigraphic unit to build the comparative chronological sequence.

2. THE SURVEY

Attention was focused on a part of the boundary wall, which is particularly interesting from an archaeological point of view.

A complex area was specifically chosen in order to test modern survey techniques. A LIDAR (terrestrial laser scanner) survey and a Photogrammetric survey were carried out in particular. A complete topographic survey was previously performed to georeference the laser and photogrammetric models, using a Topcon 8001A total station. Several markers were uniformly placed on the target object. A larger number than it was necessary for the georeferencing operations was used. This however was useful for the calibration of the images, which was carried out using a software developed by the geomatic research group of the Politecnico di Torino.

A digital reflex camera Kodak pro 14N, with ~13.5 Mpixels and a CMOS 24x36 sensor was used for the photogrammetric survey. The CMOS sensor provided images with a good definition of the radiometric borders. There was however a certain decay in the border areas of the images, which was evaluated as 5% of the width of the photograms.

The photogrammetric model covered the analysed area using four images, acquired 12m from the object and with a 80% longitudinal overlay. It was decided to use only digital equipment in order to test a rapid methodology. When digital equipment is used, photogrammetry becomes a very quick technique: *in situ*, there is the chance of immediately viewing the photos, and seeing if they have turned out as planned; it is possible to immediately pass to *in office* operations, because there is no waste of time due to development and digitalisation processes; radiometry can be adjusted via software, and digital images have no problems of long-term deformations; moreover, the internal orientation process is automatic, and complex computations are possible.

The LIDAR (terrestrial laser scanner) survey was carried out using a Riegl LMS-Z420i "time of flight" laser scanner equipped with a Nikon D1x digital camera mounted on it. The area of interest was acquired with a single scan with a resolution of 20 mgon. A laser scanning machine can be considered as a high automation reflectorless total station; by means of a laser based measurement of distance and accurate angular movement, a target object is sampled in a regular mesh of 3D points.

3. DATA PROCESSING

The aim of this research work was to test and compare survey products obtained by integrating different methodologies (digital photogrammetry, LIDAR, topographic survey). The acquired data was processed to obtain four survey products.

- Rectification
- Orthophotos
- 3D coloured model
- Solid Images

By means of a comparison, the opportunities and limits of each product were highlighted, in an archaeologist diagnosis of a historical building. Not only the accuracy and the quality of the products were considered, but also their applicability and availability in an archaeological context, analysing the times, costs and skills required for each technique.

3.1 Rectification

The data processing started with the simple rectification of the digital images. RDF software was used. This software was developed by the University of Venice, and it is available free of charge for research and education purposes. Rectified photography relies on the fact that the photograph taken square on to a completely flat plane is analogous to an orthographic projection of that plane. For this reason it is suitable when a object is completely flat. If the surface of the object is not plane, the rectification will produce scale errors. These may be acceptable if they are within the scale tolerance requirements for the survey. Large variations in the surface however mean that an orthophoto will be required. Rectification is a very cheap method and could provide a tool for the first analysis of an object. It is not necessary to use any particular equipment as it is sufficient to acquire digital images and the coordinates of four points on the object.

3.2 Orhtophoto

The orthophoto is a more complex survey product than rectification. It is a digital image where the distortions due to the image perspective are corrected. The geometry of a particular survey object is obtained by orthogonal projection of each pixel of a digital image onto a 3D surface model. In this way, the original perspective representation is transformed into an equivalent metrically correct image but its radiometry decays because of the resampling process. An orthophoto is a metrically correct photographic representation of an object, it is possible to measure distances (in a known scale factor) and read coordinates on it.

The procedure necessary to obtain an orthophoto requires a Dense Digital Surface Model. One of the most interesting applications of LIDAR instruments is that they can be used to quickly and economically create DDSM; the use of other techniques (e.g. total stations, photogrammetry) would be an incredibly time-consuming process. It is necessary to use a specific procedure for the production of an orthophoto [Dequal et al., 2001]. The high cost of the equipment and software, means that producing an orthophoto is much more expensive than a rectification. Operators with specific skills are also required.

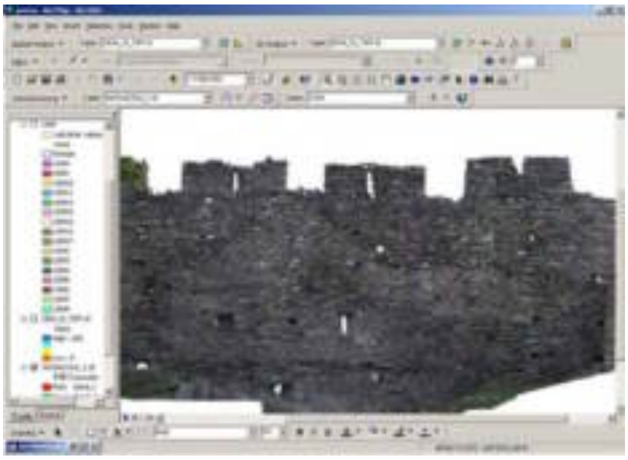

Figure 3. Orthophoto

A good quality survey product can however be acquired, in which the object is represented as it really appears, without the introduction of codes or symbology as used in a topographic survey. An unskilled user can understand and correctly read an orthophoto, while the correct interpretation of a topographic survey requires a specific technical background.

As 3D supports are still not popular among users, orthophotos could also be used as a familiar base for a GIS. This in fact could be an useful tool for the stratigraphic analysis of the boundary wall made by archaeological experts: the vector elements of the stratigraphic units could be created and alphanumeric data could be associated to them.

3.3 3D Model

Most of laser scanner machines can nowadays have a digital camera mounted on them: in this way it is possible to immediately assign a RGB information to each point. When the previously mentioned instruments (Riegl LMS Z420i Laser Scanner and Nikon D1x camera) are used, the data (point clouds and images) are stored in a single reference frame.

Figure 4. 3D model

A navigable 3D model could be easily generated. This kind of model is an extremely topical and useful tool to make a representation of a complex object. It has a remarkable impact on the public and it can immediately point out the shape of the object. However, an untrained user could find this representation not so easy to deal with. In fact it is very difficult to extract data from it. For example sections with a horizontal and vertical plane in the different zones of interest can be performed. But it is necessary to reduce the amount of processing data before the processing. Without reducing data, the creation of a section from the whole point cloud takes too much time because it uses redundant data. As these models are heavy data processing products, a dedicated computer is required. Nevertheless, it is possible to produce low resolution models by resampling the data before they are processed. Obviously some information could be lost during the resampling process.

3.4 Solid Image

An interesting recently conceived tool, that can be easily created by adopting photogrammetry and LIDAR techniques, is the socalled *solid image*. The solid image turns the philosophy of orthophotos upside down: the original radiometric contents remain unaltered and 3D information is added to it, by reprojecting the DDSM. In this way it is possible, through a common photo looking 2D interface, to have the 3D coordinates of each point in the image, and to use a set of predefined tools to perform analysis and measurements. This product can be created using a specific software called LSR2004® which was developed by the Politecnico di Torino geomatics research team. It can also be used with common commercial software such as Adobe Photoshop®, using a free plug-in. It lets the user access and manage 3D data by simply viewing a 2D monoscopic image; it adds correct 3D metric information to simple photos, so that information is much easier to be accessed by people who are not survey experts. The solid image lets the user access data on reflectivity and distances acquired by the laser sensor.

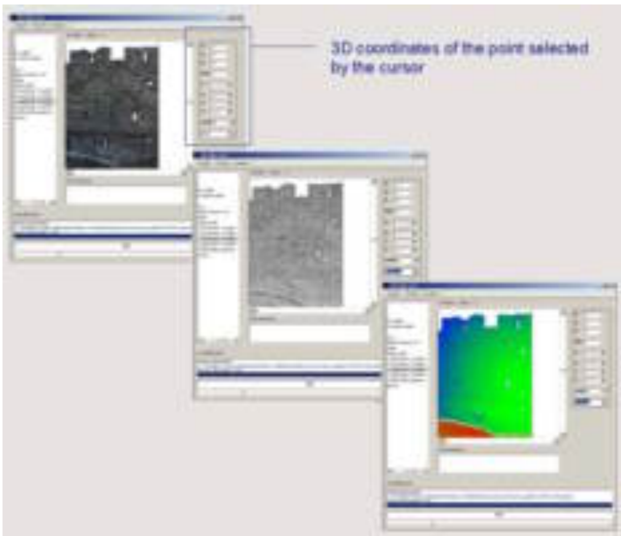

Figura 5. Solid Image. RGB image, reflectivity data, distances

In this test it was interesting to try the use of photos from different cameras: the laser machine was equipped with a digital camera, and other photos were taken in a normal photogrammetric work, therefore a greater number of images was available. In both cases, it is possible to obtain *solid image,* but the use of the camera mounted on the laser scanner machine, makes it possible to immediately obtain the external orientation parameters of the photos. This data can be acquired directly from the scan acquisition. In this way there is no need for a time consuming orientation process; the main disadvantage is to be bound by the chosen scan positions: to sample the object in an accurate way, a proper distance has to be adopted for the taking, and this can limit the field of view of the photos. Instead Figure 6 instead shows the solid image that was achieved with a Kodak pro 14N camera. As can be seen it is less limited by the sensor field of view.

Figure 6. Solid image achieved with a Kodak pro 14Ncamera

The solid image permits the user to insert vector points in the project by recognizing them in the image, in this way it is possible to select objects of interest. This offers great potentiality compared to photogrammetry: there is no intermediation involved in choosing which elements of interest have to be returned.

4. CONCLUSIONS

Correct documentation is the proper way of dealing with historical buildings. The choice of a unique reference system and the integrated use of modern survey techniques makes it possible to have an accurate geometric base, built with the best benefit/cost ratio. The building up of a GIS should make it possible to store all the different study results and information, which can lead to an ordinary or extraordinary restoration action.

The Orthophoto is particularly appreciate by archaeologists and restoration specialists especially because it can be used as a geometric base for a GIS in which surveys and alphanumeric data can be stored together. On the other hand an orthophoto needs a complex and time consuming procedure, and it requires operators with specific skills.

The study cases showed the potential of the *solid image:* this product could be used in many different situations in the near future. This is due in particular to three reasons: the automation of the production process, its user friendly approach (in fact there is 3D information in a 2D environment, which is easier to manage), and the completeness of the 3D information joined to an RGB image.

Moreover the creation of this tool is highly automated; it makes use in the best way of the potential of the advanced technologies that are available today, such as digital photogrammetry and the LIDAR technique. It also speeds up the creation of a final result, from which non specialised operators can select interesting elements and can eventually decide to deepen the study of the object by creating stereoscopic models, or 3D surface models when necessary.

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ACKNOWLEDGEMENTS

We wish to thank all the research groups involved in the project for the friendly collaboration and the Archaeological and Cultural Heritage Safeguard Office of Aosta Valley, which coordinated the project. We would like to thank in particular doc. Maria Antonina Cavallaro for her essential support.