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COMPLEX 3D HERITAGE ARCHITECTURES ACCESSIBLE ON THE WEB

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Abstract:

3D digitization, based on active or passive sensors, is a need for all man-made or natural heritage structures. It is indeed important to digitally preserve our past using the latest ICT solutions to protect and valorize it. This paper presents a collaborative work for the 3D surveying of a complex heritage monument, its annotation and segmentation for semantic reasons and the final access on the web for dissemination and valorization purposes. We report a scalable methodology for 3D surveying and exploration of large 3D results. The case study is a large castle decorated with frescoes and ornamental elements which was surveyed using photogrammetry. The 3D results (dense coloured point clouds) are enriched with metadata and historical information and shared on the Internet using a customized point-based viewer.

Key words: cultural heritage, documentation, 3D reconstruction, valorization, web-based access

1. Introduction

The continuous improvement and availability of 3D digitization solutions as well as the proliferation of interactive methods for 3D data access and sharing are reshaping how we digitally preserve, study, learn and even access information about our environment. People nowadays are constantly connected to information using Internet browsers even on mobile devices and many software packages allow the generation of 3D data without any particular technical knowledge. These two aspects play an important role in the Cultural Heritage sector where detailed 3D information is necessary to fully represent, inspect and valorize a heritage site, monument or artefact. At the same time, VR/AR applications, virtual tours, web-based 3D access, mobile applications and e-collections are fast growing technologies that have significantly altered the field of Digital Cultural Heritage (Callieri et al., 2013; Di Benedetto *et al.* 2014; Evans *et al.* 2014; Marton *et al.* 2014). For these reasons the actual challenge for ICT technologies in the heritage sector is to provide innovative solutions for sharing knowledge about the heritage building, increasing its prominence, augmenting the possibilities of interactions with its digital models and improving its commercial viability.

This paper presents a scalable methodology developed to survey large architectures and explore the realized segmented and enriched 3D data online. The monument under study is the Buonconsiglio castle in Trento (Italy), the largest and most important monumental complex of the Trentino - Alto Adige region (Fig. 1). It was the residence of the prince-bishops of Trento from the 13th century to the end of the 18th century when it started to be used as a barrack and then as Austrian military headquarter until the end of the First World War. Following its restoration in 1924, it became a National Museum and since 1973 it belongs to the Autonomous Province of Trento. The castle is composed of a series of buildings of different eras, enclosed by walls and positioned slightly higher than the city.

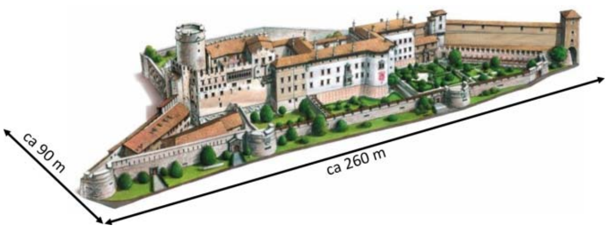

Figure 1: A sketch of the Buonconsiglio castle in Trento, Italy.

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The work hereafter presented is focused on the multi-resolution 3D survey of the entire outdoor structure of the castle and of some important internal rooms and structures. The results were enriched with annotations and historical information for dissemination purposes. All the results are stored in an online point-based viewer available online at http://3dom.fbk.eu/repository/buonconsiglio_castle/index.html.

2. Image-based 3D surveying

Surveying complex architectural objects requires a detailed prior planning in order to ensure the data completeness and, overall, the proper data assembling (Remondino *et al.* 2013). Due to the complexity of the scenarios, time and personnel restrictions, image-based techniques were considered as the best methodology for the 3D reconstruction of the castle.

A 3D aerial point cloud with ca. 10cm resolution was available from previous projects, as well as idealized plans of each floor of the castle in raster format. Therefore, 3D information about the upper parts (roofs) of the castle was already recorded, while the facades and other vertical surfaces were incomplete or totally missing. The plans provided for each floor could be used to roughly locate the interior rooms of interest that were to be digitised. A multi-resolution approach was selected: for the interior part of the castle (rooms) an average GSD smaller than 5mm was selected due to the presence of highly detailed decorative elements and frescos on ceilings and walls; whereas for the facades and the exterior walls, given the aerial point cloud, a GSD of 1cm was considered sufficient.

The image-based survey was performed considering the following aspects:

(i) cameras: two full-frame SRL cameras were mainly used, but additional lower resolution DSRL cameras were employed for the interior rooms where the distance to the object was short enough to obtain the desired GSD.
(ii) objectives/lenses: long focal lengths with full frame cameras were used for the external walls acquisition when available, whereas short focal lengths were employed for small internal rooms and narrow corridors. The optimal combination of cameras and lenses ensured the required/planned GSDs were achieved.
(iii) lighting conditions: a diffuse illumination system was chosen for indoor image acquisitions in poorly-illuminated areas, while a careful combination of aperture and exposure time was the option where additional illumination was not allowed. Increasing the aperture, the changes of the depth of field for short focus distances were also taken into consideration in order to avoid blurry areas on the images.
As the acquisition was performed during different days and under varying lighting conditions, white balance correction (white/grey card) was applied before each acquisition.
(iv) image format: RAW format enables further post-processing of the images, radiometric correction and no compression artefacts. Furthermore, in areas where colorimetry was critical (e.g. rooms covered by frescos like Torre Aquila), colour chart calibration was also employed.
(v) scaling and referencing: for a metric result a reference or scale is needed. For the internal rooms, either a scale bar or several distance measurements were taken. For the external facades and walls, common points on the overlapping areas between the aerial point cloud and the point cloud of the facades were used for referencing

In total, more than 2000 images were collected for the complete acquisition of the external part of the castle, whereas about 300 images were acquired for each of the castle rooms. All datasets were processed combining various state-of-the-art software applications (Agisoft PhotoScan, aSPECT3D and SURE). It was decided to (i) deliver the surveying results in the form of a dense, coloured 3D point clouds, direct output of the image-based workflow, (ii) combine the geometric 3D data with metadata, paradata and annotations (Section 3) and (iii) let free online access to the results (Section 4).

3. Annotations and semantics

The London Charter and the Sevilla Principles (Denard 2009; Lopez-Menchero and Grande 2011) clearly express the need for highlighting the intellectual integrity of the methods in relation to the outcome provided. They also underline how a set of principles is needed to ensure that digital heritage visualisation is, at least, as intellectually and technically rigorous (Denard 2009). Following such suggestions and in order to tackle the complexity of the process employed to deliver a final scientific product (therefore reviewable in its basic composition), it was decided to document the various phases of the castle's survey using the conceptual structure presented in (Carboni *et al.* 2016). Such choice was made in order to document the process provenance and therefore *"the sources of information, such as entities and processes, involved in producing or delivering an artefact"* (Missier *et al.* 2013). The aim was to normalise and preserve the information about the used methodology (normally called "paradata"), as well as to present to the experts the technical and scientific approach employed. This methodology, focusing on documenting the event and not only on the subject of the digitization, allow the documentation of the different acquisition activities that compose an acquisition project (Fig. 2), keeping records of the different parameters used.

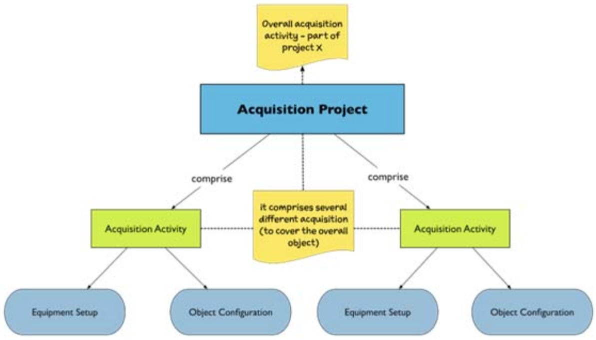


Figure 2: Schema followed for the documentation of the different agencies and subjects during the acquisitions events.

The information regarding the geometric construction of the 3D point cloud of the castle was documented using the methodology cited above. The information, together with the metadata of the surveyed scenes, was registered and put in relation with each of the performed acquisitions, in order to have, in a web interface, not only the result in 3D, but a set of elements describing the shooting, the object, the environment, and the post-processing information, which are essential for assessing the results by the professional public.

This methodology allows the public to see/read/access/enjoy the composition of the various parts of the castle as a single unit, or as an overall product, allowing the exploration of the different details of a multi-actor and multi-resolution type of acquisition.

4. Web point-based visualization

For the visualization of dense point cloud datasets, the Potree WebGL open source viewer (version: 1.4RC) was used. This solution (i.e. point-based rendering) has the main advantage of being specifically developed for rendering large point clouds using standard web-based technologies that work within a web browser.

The castle raw point clouds were first cleaned, resampled and exported in .las/.laz format. The .laz files were then promptly re-encoded in an octree data structure using a converter (Schütz 2014).

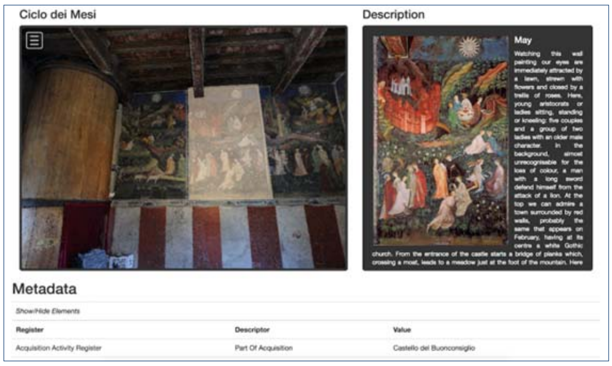
The visualisation was enriched with interactive points of interest (POI) linked to additional visualizations of internal rooms or to textual description of the content of a specific part of the castle e.g. about frescoes (Fig. 3b).

The results were presented in a web interface, which, targeting both professional and cultural heritage enthusiast, allow the visualisation and the exploration of 3D data (combination of aerial with terrestrial data) (Fig. 3a), 2D information (raster plans and images), textual description (iconography) together with the semantic information of the process, providing furthermore the possibility to perform various user interaction (e.g. distance or surface measurements) within the 3D model.

5. Conclusions

The article has presented the 3D surveying of a complex heritage site. The collected and enriched 3D data are then used for valorization, dissemination and communication purposes by means of a web-based visualisation of the point cloud linked to annotations and other semantic information. The current paper highlights the importance of the collaborative work of a multidisciplinary team when it comes to a holistic documentation approach of large scale monuments realized not only for geometric documentation but also for valorization purposes. The combined expertise from different scientific domains can significantly speed up and, more importantly, improve the documentation processing steps, from acquisition to visualisation and dissemination.

a)



b)

Figure 3: a) The initial visualization with the castle and the surrounding urban area; b) POI (Torre Aquila) with its frescoes.

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