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Integrated Survey and 3D Processing on Enea CRESCO Platform: the Case Study of San Nicola in Carcere in Rome

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Abstract. This paper shows the experimental activities carried out by a joint research group on the case study of the Basilica di San Nicola in Carcere in Rome, concerning the integration of different 3D reconstruction technologies in the Cultural Heritage domain. Dataset obtained from laser scanner and photogrammetry, were processed on a remote platform based on the powerful ENEA computational infrastructure, in order to analyse the dense clouds, to compare them and to improve the quality of the data. This paper also shows the efforts to upgrade this platform and the optimisation of the processes.

1. Introduction

1.1. Objectives and areas of intervention

In the past few years a growing interest in the field of digital reconstruction techniques and related analysis processes has marked out the Cultural Heritage studies. Thanks to those tools it is possible to share knowledge in a more efficient way, allowing both collaboration among researchers and remote access to heritage for the public. For this reason a good set of performant software and hardware tools that permits 3D reconstruction and related information enrichment are fundamental. The activities described in this paper concern the optimization of the ecosystem components dedicated to the acquisition of datasets from instrumental surveys carried out with different methodologies and the processing of three-dimensional analytical models to support research activities. The optimization of the It@cha [1] platform on ENEAGRID/CRESCO [2] infrastructure is part of the research project promoted by Enea and Roma Tre University for joint studies on Cultural Heritage. The objective of the collaboration, born within the framework of the DTC Lazio [3] in 2019, is to enable the acquisition, management and presentation of digital twins of cultural heritage assets, through advanced software services integrated in a single digital ecosystem dedicated to the knowledge of cultural heritage.

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2. Methodologies

2.1. Use of It@cha platform

It@cha "Tecnologie Italiane per applicazioni avanzate nei Beni Culturali" is the platform developed by ENEA for the project financed by the National Operational Program (PON) "Ricerca e Competitività 2007-2013". It is hosted on the ENEAGRID/CRESCO HPC infrastructure, a service oriented system for high performance computing, managed and developed by TERIN-ICT, a division of the ENEA Energy Technology Department, connected in a Wide Area Network. It@cha is a system that allows the remote use of software for 3D processing and modelling by exploiting the computing resources of a pool of machines of the infrastructure, dedicated to graphic applications. In particular, the platform offers the possibility to obtain photogrammetric reconstructions through the software Agisoft Metashape, their manipulation through the software Meshlab (developed by ISTI-CNR) plus other open-source software for three-dimensional graphic processing. The remote control of these applications is managed by a software component of the platform that redirects the rendering by exploiting the resources of the remote servers. This therefore allows both hard processing and rendering of the graphical environment. The pool of machines serving this platform is shown, with their main characteristics, in Table 1.

Table 1: It@cha platform hardware characteristics.

Hostname	CPU	Memory	GPU
`cresco6-nvi1` `cresco6-nvi2`	2x Intel Xeon Platinum 8160 2.10GHz 48 cores	192 GB	Nvidia Tesla V100 32 GB
`cresco4-nvi1`	2x Intel Xeon E5-2680 2.80 GHz 20 cores	64 GB	2x Nvidia K40m 12GB

Another software component of the infrastructure has the task to manage the job queues to allow a proper usage of computational resources and to avoid system overloads.

2.2. Optimization on It@cha platform

The optimization of the It@cha platform concerned the workflows through the monitoring of computing resources during the massive use of 3D reconstruction and 3D modeling software. This allowed us to identify strategies to improve the performance of the platform and consequently enhance the analytical capabilities of the software used.

3. Case study

3.1. The Basilica of San Nicola in Carcere in Rome

The Basilica of San Nicola in Carcere (Figure 1) stands on the archaeological ruins of three temples built in the Forum Olitorio between the third century BC and the second century BC, dedicated to Juno Sospita, Janus and Spes, still visible outside the church [4].

The first structure of the Basilica was built in this area in the 6th century on the ruins of the Foro Olitorio and received its name *in carcere* from a prison present there, the "Carcer ad Elephantum". The latter, which can still be visited, is in a significant state of deterioration due to the thermo-hygrometric situation that compromises the preservation of the superficial layer of the masonry and does not allow a precise stratigraphic reading. Therefore it was decided to concentrate the surveys, and the subsequent elaborations, in the crypt.

Figure 1: The Basilica of San Nicola in Carcere (left), the crypt (right).

3.2. The surveys

Thanks to the instrumentation provided by Riltec (Department of Architecture - University of Roma Tre - coord. Prof. Marco Canciani), the laser scanner survey of the entire church of San Nicola represented the first phase of acquisition of metric and dimensional data. It has also allowed us to understand how the volumes of the upper part of the church insisted on the underground rooms of the crypt, revealing the structural continuity of the two overlapping environments, particularly important to assess any phenomena of rising damp to the environments of the church. Subsequently, two photogrammetric survey campaigns have been carried out, with the aim of elaborating, through the SfM methodology [5], a dense cloud and detailed orthophotos of the masonry inside the crypt.

3.3. Monitoring data flow

The interoperability between software in the It@cha platform has allowed us to define a pipeline for the management of point clouds obtained from the processing of data sets acquired. During the software processing phases, the metrics of the hardware computing resources used were monitored in order to estimate the performance of each step of the SfM algorithm. In particular, data related to CPU, memory and GPU usage were monitored. Among other tests, just for example of the analysis typologies, a GPU impact evaluation was carried out. This test is particularly important due to the fact that not every step of the SfM algorithm uses the graphical acceleration. This could bring no advantages and, in some cases, could even worsen the entire processing time. To evaluate this impact, the elapsed time for each SfM step has been measured both with and without GPU, as shown in Figure 2.

This measure had allowed to define an index, the *change percentage* p_c which has been calculated with the formula:

$$p_c = \frac{t_A - t_N}{t_N} \cdot 100 \qquad (1)$$

where:

t_A is the elapsed time with GPU

t_N is the elapsed time without GPU

Thanks to this index and other analyses a set of optimized workflows have been designed and an on platform *jobs submission policy* has been defined. With these improvements a more focused attention has been moved to dense cloud comparison.

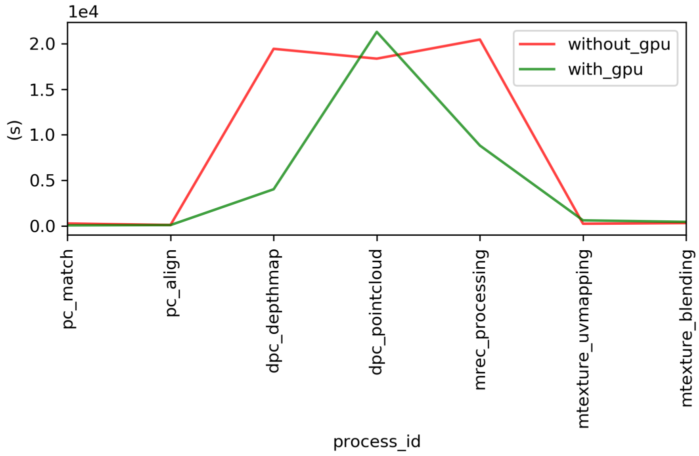

Figure 2: SfM single step elapsed time (s)

3.4. Geometric analyses

The computational power of the platform has allowed it to elaborate the point cloud, starting from the data acquired during the photogrammetric survey, with the maximum accuracy allowed by the Agisoft Metashape software, considerably reducing the calculation time. The dense point cloud thus obtained was compared with the points acquired by laser scanner, in order to verify the geometric and dimensional fidelity of the survey carried out with SfM methodology. The comparison between the two dense clouds was made through the software Cloud Compare (Figure 3), through which it was possible to calculate the square deviation between the two clouds, then display the areas where the distance between the two clouds was minimum and maximum.

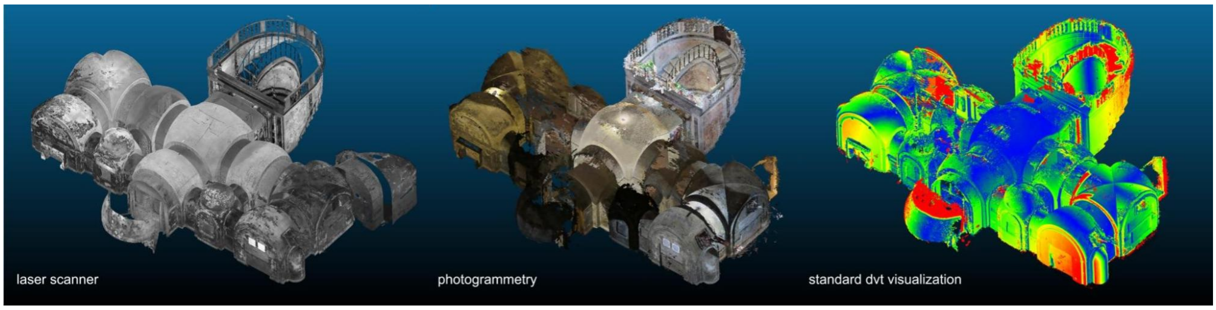

Figure 3: The comparison through CloudCompare software of the clouds obtained from laser scanner and SfM (RMS difference 1,4 cm).

Subsequently, through the calculation of the normals and the analysis of their dip and direction, it was possible to perform analysis of the material consistency of the wall surfaces of the crypt. In particular, the masonry portions of the first corridor of the hypogeal rooms were analysed. The objective was to isolate materials and patterns coherent with each other to facilitate the stratigraphic reading through the recognition of the surface characteristics of the materials. The elaborations bring to evidence, in fact, the different patterns that characterise the masonry (Figure 4) through the visualisation of the normals built in each point and relative to a 5 cm circular plane. Further analysis of the surfaces allowed to highlight the geometric

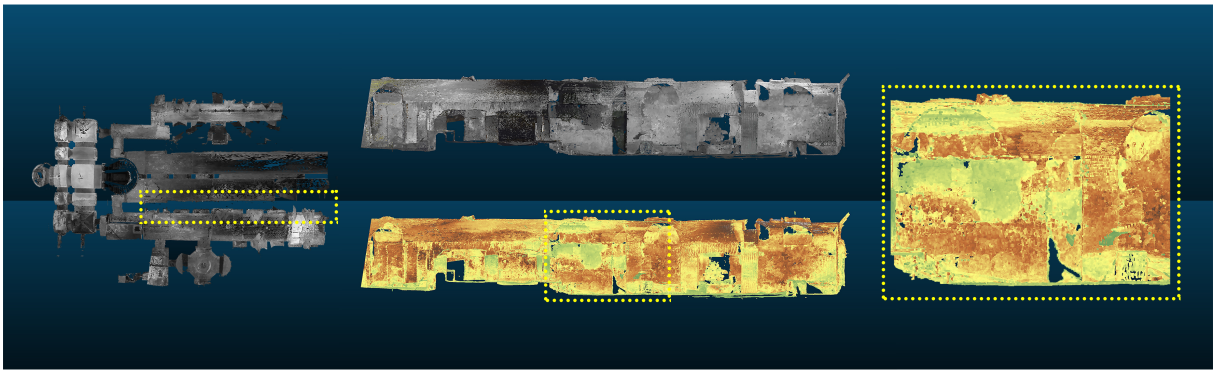

Figure 4: Computation of the normal, highlighting the differences between the masonry patterns.

deviations from the average planes in order to detect and evaluate any significant deviations. In particular, the structural deviations of one vault of the "carceri" have been analysed. The compute of the surface variation and the visualization of the distance map to 3D best fitting surface, highlights the portions of masonry that represent a possible structural deviations to eventually monitoring (Figure 5).

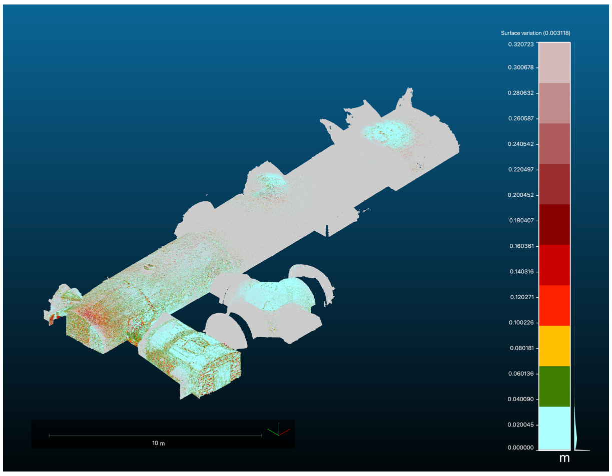

Figure 5: Surface variation diagram of the vault of the crypt, highlighting the distance of the cloud points from the best fitting plane.

3.5. The Open Digital Twins Ecosystem
A cloud native web app to allow data management is under development [6]. This tool is the module of a more wide and innovative ecosystem with a micro-services architecture named *Open Digital Twins*. Such ecosystem is designed to flank the It@cha platform for what concern data storage and visualization. A first Proof of Concept (Figure 6) of this module allow to upload, store and visualize data such as publications, images and 3D reconstructions models with their related metadata (including the geographical references). While these last one are stored in a modern database that allow even *full text* searches, the data are stored in a distributed file system to ensure their availability and persistence.

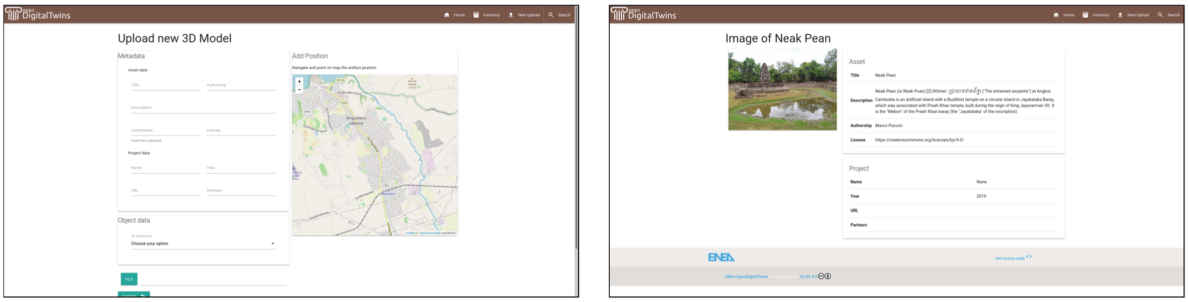

Figure 6: Open Digital Twins Ecosystem. Two examples: the 3D model upload page (left) and the result page for an image with metadata (right).

With this tool, research products can be easily stored, shared and enriched among researchers community, students and stakeholders.

4. Perspectives

The possibility to perform all the software elaborations in a single environment that can be managed remotely, the identification of an optimised pipeline for the software elaborations and the calculation capacity ensured by the It@cha platform, allow to outline some of the future goals: through further experimentation it is foreseen the implementation of further open source software steps [7] for the dimensional and geometric analysis, the comparison and the visualization in multi-resolution mode of the point clouds, as well as the automatic recognition of surface patterns and constructive elements.

Acknowledgments

All the activities described above are carried on the ENEAGRID/CRESCO infrastructure. Thanks to the fundamental support of ENEAGRID/CRESCO team in terms of computing resources, networking and know how it was possible to carry out this work.

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