DOI: 10.26314/GARR-Conf23-proceedings-04

The IT@CHA Virtual Lab: a set of enabling technologies for Digital Twin implementation and enrichment in Cultural Heritage

Marialuisa Mongelli, Beatrice Calosso, Samuele Pierattini, Marco Puccini, Giovanni Ponti

ENEA

Abstract. The ongoing digital revolution is outlining efficient ways of integrating Digital Twin, 3D computing graphics, and structural behavior simulations in all the governance phasis of cultural assets with the final goal of developing new models for conservation and end-users' engagement. Thus, the platform IT@CHA (Italian Technologies for advanced applications on CH), has been updated since develops the virtual Lab: a multimedia laboratory embedded in the Computational RESsearch Centre on COmplex systems, CRESCO. The paper shows the capabilities of the IT@CHA Virtual Lab about the entire numerical modelling chain, useful on cultural assets, according to FAIR principles focused at highlighting its interoperability, scalability, and versatility. Users of the Virtual Lab can develop numerical models and manage 3D data to support the preservation phase of the asset.

Keywords. Digital Twin, data interoperability, Open Science & FAIR Data, CH enhancement

Introduzione

CRESCO (https://www.eneagrid.enea.it/CRESCOportal/) is the High-Performance Computing (HPC) facility developed by ENEA, with remote web access, able to share HPC resources, structural computation, and graphics resources. It is a complex infrastructure based on a cluster of 434 nodes (servers) each with top level hardware resources that brings to 20832 cores. All those resources are available through a remote system based on the SSH protocol that allows users to work with. That infrastructure has a unique authentication system and with both the General Parallel File System (GPFS, brand name IBM Spectrum Scale) and Andrew File System (AFS) makes it possible for users to have a personal and a shared environment to work with. In particular, the GPFS is a high-performance clustered file system, optimized for huge workload such as the required for HPC that can be used like a shared area; whereas AFS is a distributed file system that allows to have the same own folders on all the nodes, like what a common user has in his own laptop or desktop device.

On top of that hardware resources some Virtual Labs (VL) are being developed during past project work packages: they are a set of software tools that use CRESCO resources, served remotely via web for researchers' activities. There are different VL for different research areas of interest. Here we present two of them: DySCo (Structural Dynamic, numerical Simulation qualification tests and vibration Control) and IT@CHA (Italian Technologies for advanced applications on Cultural Heritage): http://www.laboratorivirtuali.enea.it/it/

prime-pagine/it-cha-virtual-lab.

1. IT@CHA Virtual Lab

The IT@CHA Virtual Lab (Figure1) is a digital platform developed for the IT@CHA project started in 2013 by ENEA (http://www.progettoitacha.it/), and still available today, with continuous updates and new features implementation. It is fully integrated in the ENEAGRID/CRESCO, where the main High-Performance Computing cluster is hosted in the ENEA Portici Research Centre. Such a platform is reachable via web thanks to dedicated servers that share graphics resources on a high-performance network, allowing the usage of professional software both proprietary and open source, for computer vision workflows. Thanks to a simplified user interface it is possible to work remotely with tools like Agisoft Photoscan, Meshlab, Nastran/Patran or Blender all inside the same environment, enforcing interoperability and integration. Storage tools like the distributed file systems AFS and IBM GPFS allow data sharing among users and software, while a novel system like E3S (Enea Sharing Staging Storage) allow to load experimental and/or computational outputs into a unique area to make it available for researchers. All these software take advantage of CRESCO computing resources that can accelerate performance.

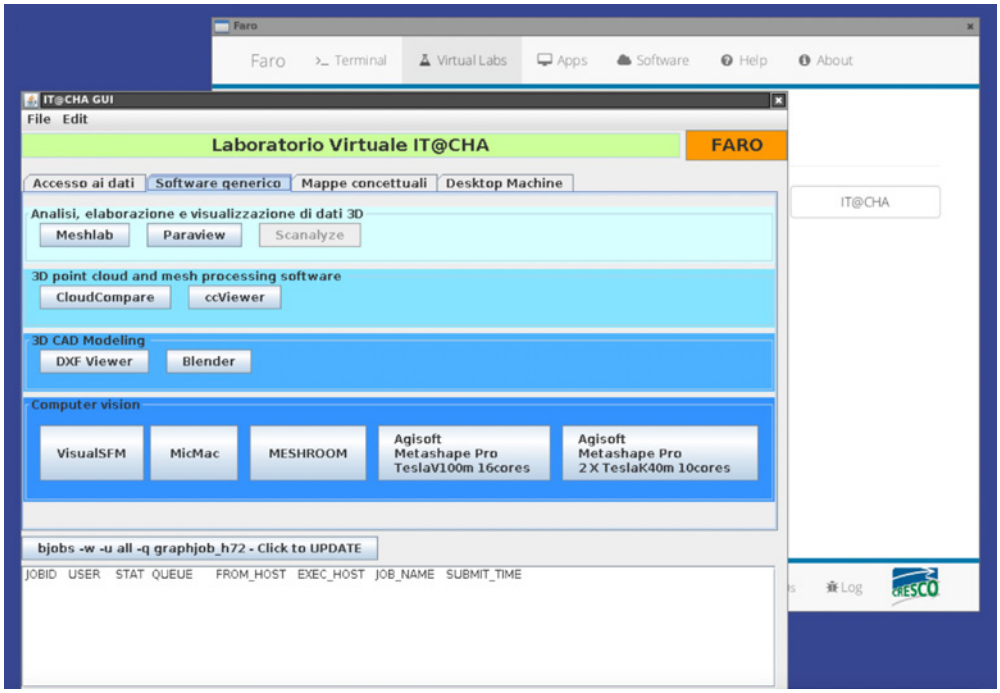


Fig. 1
The interface of the IT@CHA Virtual Lab

New implementations and features have been developed in the last few years, such as a dedicated modern NoSQL database to archive metadata of digital objects, making it available for further works and research and to easily integrate with advanced viewer services like 3D HOP for 3D objects visualization or IIPImage server for Gigapixel High resolution

images. Such new features are hosted on a dedicated virtual machine (heritagescience.portici.enea.it) managed into a VMWare cluster to ensure his redundancy and backup.
In the last five years, starting from the experience of IT@CHA and the collaborations within the Lazio Region Culture Technology District Center of Excellence (DTC Lazio - https://dtclazio.it/), the ENEA Digital Twin Environment for Cultural Heritage was implemented also thanks to D-TECH (Digital Twins for Cultural Heritage) project that is going on, with the aim of building a distributed infrastructure for Digital Twin management for cultural assets, adopting the Data Mesh paradigm to leave control over their data as much as possible in the hands of heritage managers.

2. Use case

The use case of the "Bridge of the Towers" in Spoleto shows features and potentiality of IT@CHA platform performed within the Resilience Enhancement of a Metropolitan Area Project (RoMA). The survey aimed at defining the state of conservation of the bridge and at ensuring its long-term preservation using numerical models, starting from a drone stereo-photogrammetric scanning to Finite Element (FE) modelling and many other monitoring techniques, to assess the bridge cracks pattern - without building scaffoldings - and its structural health by a multidisciplinary approach that allows their mutual validation.
The scanning produced 818 HD images (38 Mpix), respectively 411 for the north side and 407 for the south one with a GSD (Ground Sample Distance) equal to 1.75 mm/pixel. Thanks to a GPS module embedded in the drone, the photos were also completely georeferenced. The images acquired during the drone flights were post-processed through the ENEA HPC resources provided by CRESCO by the Structure from Motion (SfM) technique, which allows to estimate and reconstruct 3D structures from two-dimensional images. The technique performs photogrammetric processing of digital images and generates 3D spatial data and a dense point cloud useful for visual effects production and indirect measurements of the objects (Figure 2-3-4).

Fig. 2
Dense cloud of the North side of the Bridge of the Towers in Spoleto

Fig. 3
Dense cloud of the South side of the Bridge of the Towers in Spoleto.

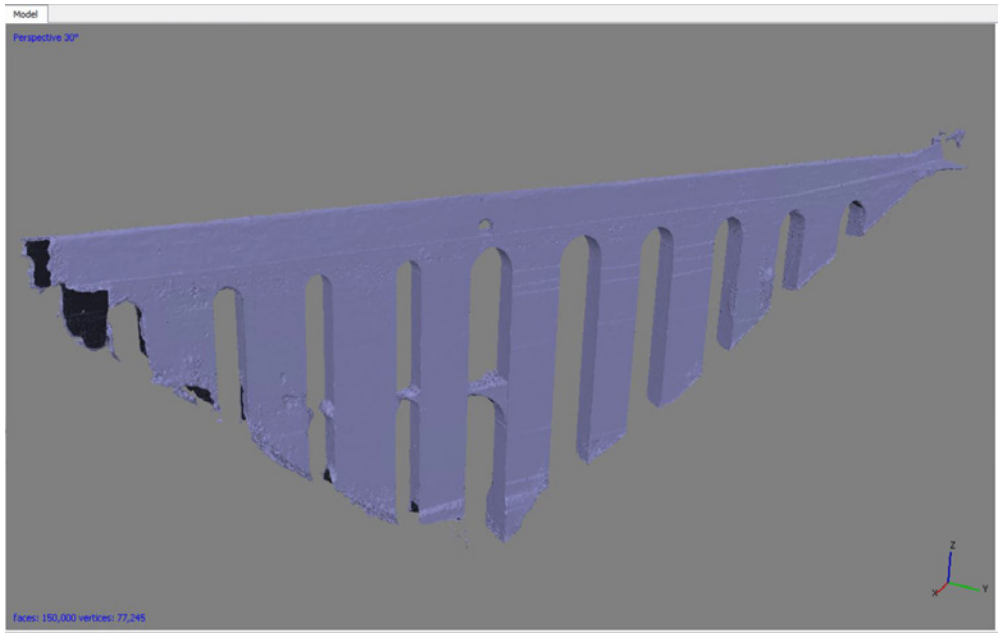


Fig. 4
Mesh of the Bridge of the Towers in Spoleto

The preliminary 3D FE model (Figure 5), performed based on geometrical survey made available by municipal offices (Figure 6-7), allowed to evaluate the most critical areas where to fix the sensors for environmental measures.

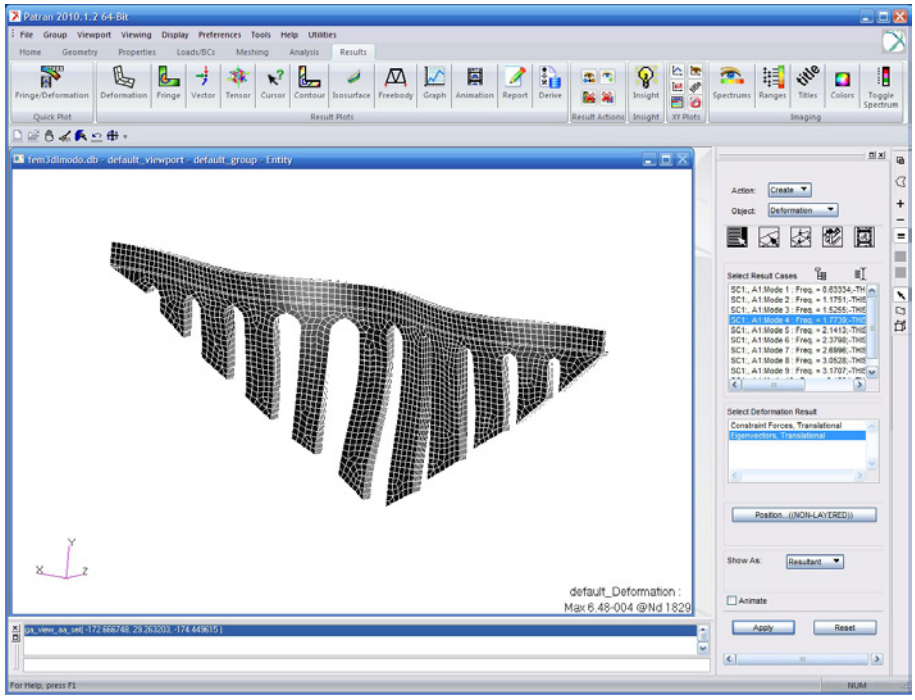


Fig. 5 Preliminary 3D FE model of the Bridge of the Towers in Spoleto

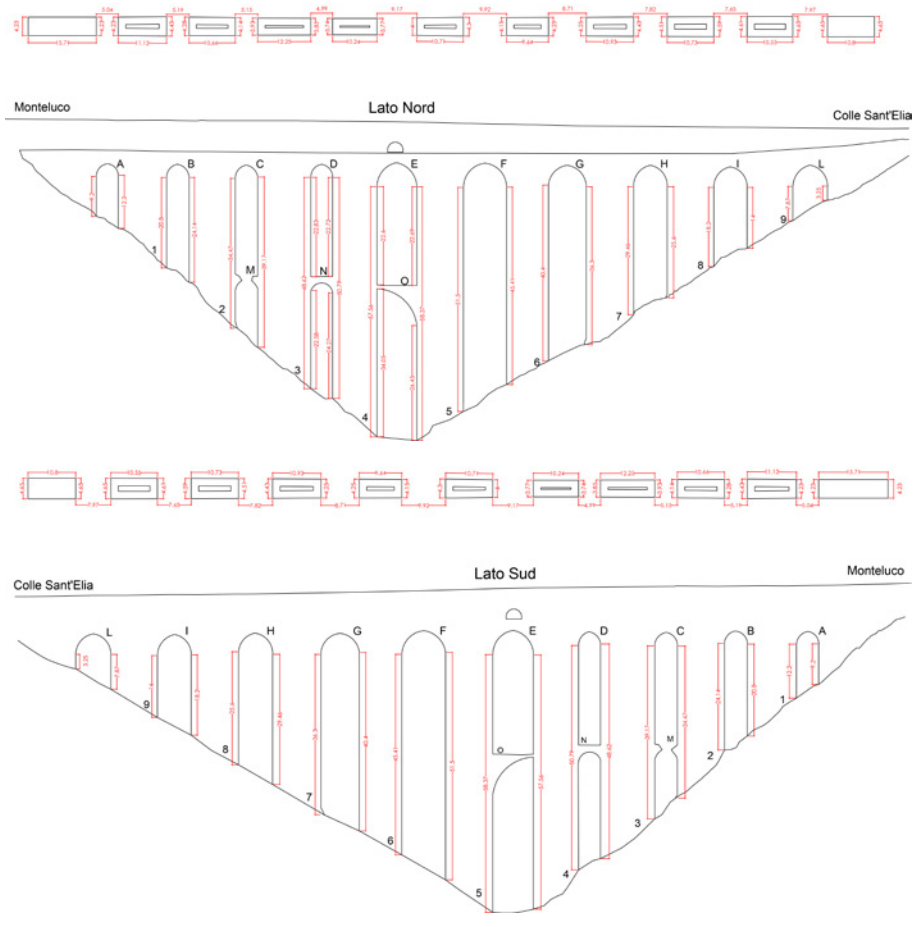


Fig. 6 Geometrical survey of the North side of the Bridge of the Towers in Spoleto

Fig. 7 Geometrical survey of the South side of the Bridge of the Towers in Spoleto

The preliminary FE model was integrated by additional geometric details at the basis of the piers, obtained by 3D photogrammetric reconstruction (Figure 8). The numerical results were then compared in terms of frequencies and modal shapes with experimental ambient vibration data, which were processed by Operational Modal Analysis (OMA) (Mongelli, M., 2017).

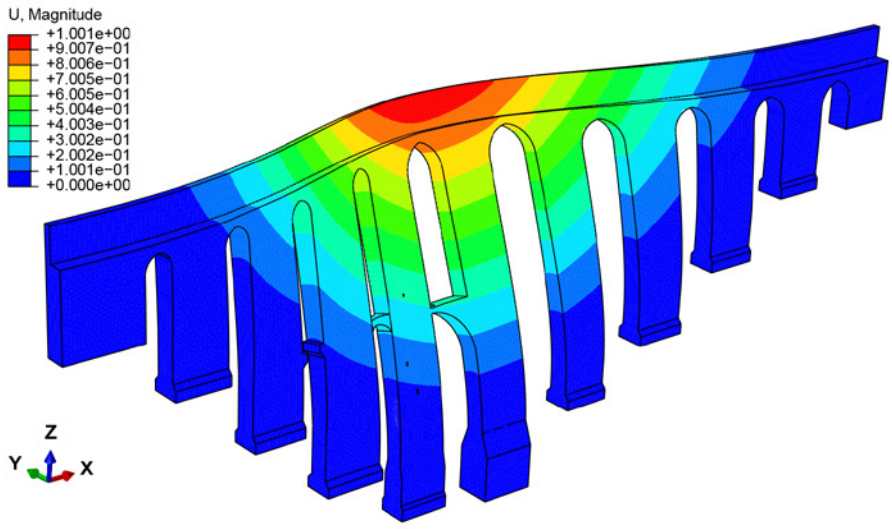


Fig. 8
FE Modal Analysis with the basis of the piers

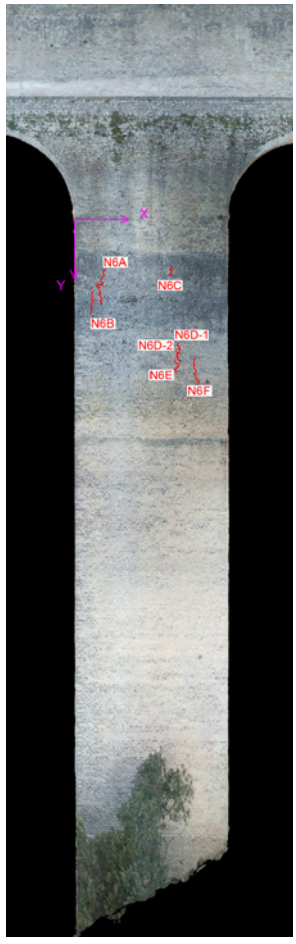


Fig. 9
Crack pattern on the pier number 6

Each identified crack was taxonomically defined in a unique and easy way (Figure 9). The indication of the damage class was defined in accordance with the macro seismic European EMS98 (http://media.gfz-potsdam.de/gfz/sec26/resources/documents/PDF/EMS-98_Original_englisch.pdf), also used by the 2nd GNDT level cards, considering five levels of damage (low, moderate, high, very high and collapse).

Conclusions

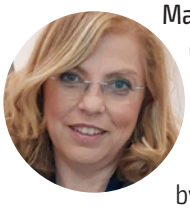
Finally, it is important to highlight that by IT@CHA Virtual Lab all the users will be able to develop numerical models and manage 3D data to support the preservation phase of cultural assets, taking advantage of some hardware and software capabilities for monitoring and planning diagnostic interventions. Moreover, the Virtual Lab makes available tools useful in the entire numerical modelling chain, from Digital twins to FE analysis, according to FAIR principles (for the integrated use of devices), focused on interoperability, scalability, and versatility. In the last analysis, it has been shown that the sharing of computing services and GARR network resources, using ENEA-GRID CRESCO infrastructure, is absolutely in accordance with the policies for green deal, and supports digital transition and the technological transfer.

References

Mongelli, M. et al., (2017), 3D Photogrammetric reconstruction by drone scanning for FE analysis and crack pattern mapping of the “Bridge of the Towers”, Spoleto, in Proc. of 5th International Conference on Mechanics of Masonry Structures Strengthened With Composite Materials (MURICO5), Bologna 28-30 June, Italy, published in Key Engineering Materials, Vol. 747 ISBN: 978-3-0357-1164-6, DOI: 10.4028/www.scientific.net/KEM.747.423.

Authors

Marialuisa Mongelli marialuisa.mongelli@enea.it



Chemical Engineering, PhD in Metallurgy. Researcher. She currently works in the team of HPC Laboratory of ENEA. Her activity is mainly directed in the cultural heritage field especially in the definition of virtual platforms for remote access to instrumentation for research services, consulting and qualification, as well as scientific computing provided by ENEA large plants and / or equipment. She is expert in numerical models' definition, from Digital Twin to FEM, and data analysis integration.

Beatrice Calosso beatrice.calosso@enea.it

PhD in Architecture History and Restoration. Degree in Arts and Humanities. Since 2003 employed in the ICT lab of the Italian National Agency ENEA. Expert in scientific communication and technological transfer. Communication specialist in funded projects on the use of technologies for CH diagnostic and conservation. Content Web Manager of project websites. Content editor and tutor in blended-learning professional training, about CH digital cataloguing instruments.

Samuele Pierattini samuele.pierattini@enea.it

High school graduation in Computer Science. Since 1989 employed at ENEA as a computer expert in applications and systems for advanced 3D visualization and 3D acquisition. Development of remote 3D visualization systems in GRID/CLOUD for the realization of ICT platforms and virtual labs. Participates in the PNRA –Italian National Project of Research in Antarctica in the activities of air photogrammetric surveys and aerial photographic images for environmental monitoring.

Marco Puccini marcopuccini@pm.me

Graduated in Physics from the University of Rome "La Sapienza", worked with CNR INM, DIMA and the Department of Molecular Medicine of "La Sapienza" as a data scientist. As a Research Fellow at the ICT Division of the TERIN Department of ENEA he was mainly involved in data management, development of cloud software solutions in different projects such as Mission Innovation IEMAP, DTECH, ECODIGIT, RAFAEL.

Giovanni Ponti giovanni.ponti@enea.it

Director of ENEA's ICT division and member of GARR CTS. PhD in Computer Engineering in 2010 (University of Calabria) focused on data modelling and data mining algorithms. ENEA researcher for 12 years with experiences in HPC, Data Science, Cloud Computing, Big Data and Data Analytics. Author of prestigious scientific publications. Member of the program committee of conferences and reviewer for prestigious journals and conferences.