

Experimental data sharing of shaking table tests on masonry structures by “Staging Storage Sharing” (E3S) system

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Abstract – With the primary aim to improve the collaboration between scientific communities working in the field of Cultural Heritage protection and conservation, the ENEA ICT team has developed a new methodology, based on the OwnCloud framework, named “E3S: ENEA Staging Storage Sharing” [1]. This architecture has been developed within the COBRA project. L'origine riferimento non è stata trovata. and it provides the real time sharing of experimental data and videos, performed by shaking table for seismic protection at the Sustainable Innovation TEChnologies (SITEC) ENEA Casaccia R.C. laboratory.

The paper shows an application of this methodology during experimental tests on two masonry walls, made up of stone and tuff blocks, that represent the poor masonry of the Italian historical buildings, to verify the behavior of innovative techniques of anti-seismic reinforcement.

INTRODUCTION

The ENEA Staging Storage Sharing (E3S) architecture is based on the OwnCloud framework and it allows to synchronize the local staging areas of the experimental Data Acquisition System (DAS) that are closed to the lab Local Area Network (LAN), with the ENEA storage area, AFS and GPFS, for world-wide sharing.

This architecture was set up for the real time sharing of experimental shaking table tests performed at the SITEC ENEA Casaccia R.C. laboratory [3].

E3S supports the whole experimental process, from the data acquisition to the calibration of Finite Element Models, reducing time needed to obtain scientific results by means real time data streaming functions.

This paper shows the effectiveness of the sharing and data streaming process, during the execution of experimental tests performed within the project for the cooperation and the scientific-technological transfer USA-Italy, named "Composites with inorganic matrix for

sustainable strengthening of architectural heritage", to verify the dynamic behaviour of historic masonry structures and test innovative techniques of reinforcement during seismic events.

The experimental data are acquired by an optoelectronic system, named 3DVision [4], which uses a constellation of NIR infrared cameras to measure the 3D positions of hundreds of passive wireless markers placed on the two structures.

As soon as the experimental data are stored locally in the laboratory DAS they are synchronized on a C3D file, that is copied on the AFS and GPFS ENEA storage areas.

The OwnCloud [5] [6] framework allows the user in charge of the test to store the experimental data in the “local staging area” through the OwnCloud web interface, only accessible from the lab LAN or, alternatively, through the OwnCloud client, which can be installed on any device.

A web application based on LAMP platform (Linux Apache MySQL PHP), named “DySCo Logbook”, is developed to collect metadata and trigger near real-time streaming of data and video of the experiment.

The DataTurbine [7] application is used to stream and share the trajectories of all the markers installed on the two walls and the videos from the test.

The experimental data are then used to calibrate, in near real-time, the Finite Element Models of the tested structures, using the computational resources offered by ENEA HPC CRESCO (Computational Research Centre for Complex Systems) ICT infrastructure [8], so as to improve the significance of next simulations and the models reliability for similar tests.

I. THE ENEA STAGING STORAGE SHARING

The ENEA Staging Storage Sharing architecture (see Fig. 1) uses the potentialities of the ENEA pre-existing services for data and file sharing, based on the AFS and GPFS file system. It takes advantage of the power of a high-bandwidth and low-latency network, consisting of

two network links with 1000 GB per second speed.

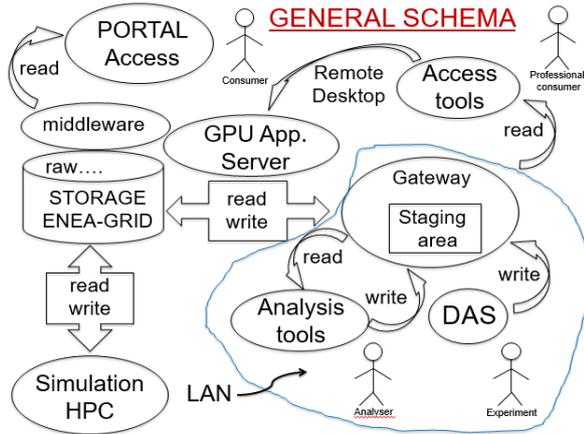


Fig. 1. E3S general schema.

The experimental data, acquired during the execution of shaking table tests by the 3DVision system, are temporarily archived in the local storage areas, called “staging areas” (SA). They are close to the lab Data Acquisition System (DAS) and they are managed by hardware components that guarantee data integrity and security.

The *staging areas* are handled by a functional component named “Gateway Node” (GWN), that belongs to the same LAN (Local Access Network) of the laboratory DAS.

Thanks to the implementation of a sync method based on the Web Distributed Authoring and Versioning (WebDav) protocol, the experimental data can be stored even when network links are not available, and their access is guaranteed by the availability of analysis and visualization tools, by a client-server model. In fact the GW node manages the synchronization process between the local staging areas and the distributed AFS cell ENEA.IT, which represents the main component of the ENEAGRID infrastructure [9] for file and data sharing, providing access services to the *storage areas*.

Those services are managed by the “Middleware Node” (MWN), the other functional component of E3S that provides cloud sharing facilities by means of the OwnCloud framework, using the ENEAGRID storage areas as back-end: it communicates with Web access portals and it ensures the access to the laboratory experimental data as well.

The last component of E3S architecture is the “GPU Application Server” (GAS), which provides an integrated graphical environment for the execution of many applications on multiple hardware platforms, based on remotely accessible Graphics Processing Units (GPU).

The access to the GPU Application Server by skilled users permits to analyze and process all the experimental data that are saved in AFS storage areas, with specific authentication and authorization criteria based on Kerberos5 protocol and particular data access privileges.

II. THE EXPERIMENTAL CAMPAIGN

The experimental tests by shaking table were performed on two masonry walls made up of typical materials of the Centre Italy historical buildings, tuff blocks and stones, as shown in Fig. 2.

The experimental campaign was part of a Italy-USA project, titled “Composites with inorganic matrix for sustainable strengthening of architectural heritage” for cooperation and technology transfer.

During the first tests session the specimens were tested without any type of reinforcement, in order to study their dynamic response in terms of magnitude and to evaluate the out of plane actions until their collapse. Subsequently the two walls were repaired and a new high-strength “composite” reinforcing fibers was tested, in order to verify their seismic capacity.

The experimental tests were performed by a 6-degree-of-freedom shaking table (4m x 4m) and the displacement data were acquired with a sampling frequency of 200 Hz, by the 3DVision motion capture system, which uses a constellation of 4 video and 10 new NIR high resolution digital MX cameras with Vicon VEGAS-4 CMOS sensors of 5 Megapixels up to 350 fps resolution.

The system is able to track the 3D trajectories of hundreds of markers placed on the two structures in the most critical areas, which came from a preliminary FE modal analysis, with easy and fast test set-up and high accuracy, providing an easy calibration of the measured volume, a greater uniformity of acquisition and a faster image processing. The NIRs have been installed around the specimens so as to cover the entire measurement volume and to optimize the camera calibration process.

During the first test session, five Italian seismic inputs (Bagnoli, Mirandola, Amatrice, Nocera and L’Aquila) were executed at increasing intensity from 25% to 125% of real accelerograms and the trajectories of each markers positioned on the structures were saved into a C3D file, produced at the end of each test step.

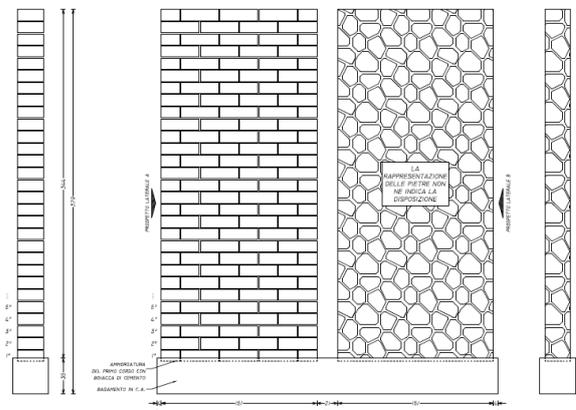


Fig. 2. Tuff blocks wall(left) - Stones wall (right)

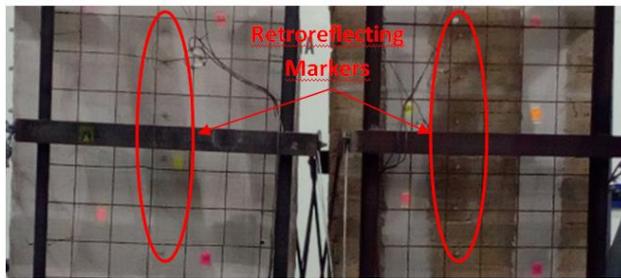
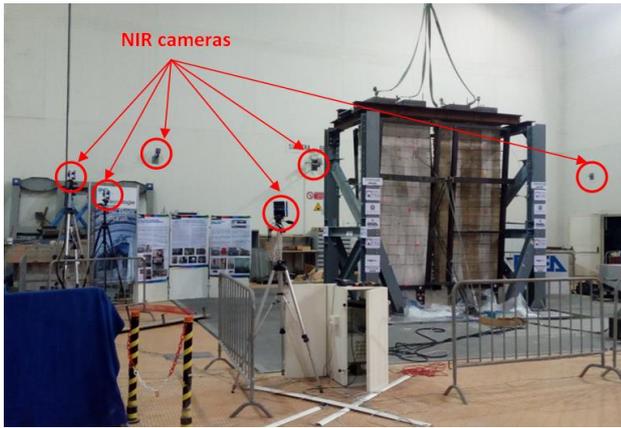


Fig. 3: Experimental tests set-up

A. Streaming and data managing by DySCo Logbook and DataTurbine application

All tests were shared in near real-time both with project partners (University of Roma Tre and University of Miami) and with other experts and researchers working in the field of seismic protection by E3S architecture, through the “DySCo Logbook” web application, the OwnCloud framework and the DataTurbine system.

The OwnCloud framework allowed the user in charge of the test to store the experimental data in the local staging area through a web interface (See Fig. 4) or, alternatively, through the client, which can be installed on any device (See Fig. 5), only accessible from the lab LAN.

A synch process, managed by the WebDav protocol, allowed to synchronize the staging area with the AFS storage area, and the experimental data were shared with remote users who can access the same web interface.

The “DySCo Logbook” application has been developed to collect all the metadata contained in the C3D files and trigger near real-time streaming of data and video of the experiments. This application, based on LAMP (Linux Apache MySQL, PHP) platforms, uses a specific database named “dyscodw” and it is made up of two section:

- “insert/modify” section;
- “view” section.

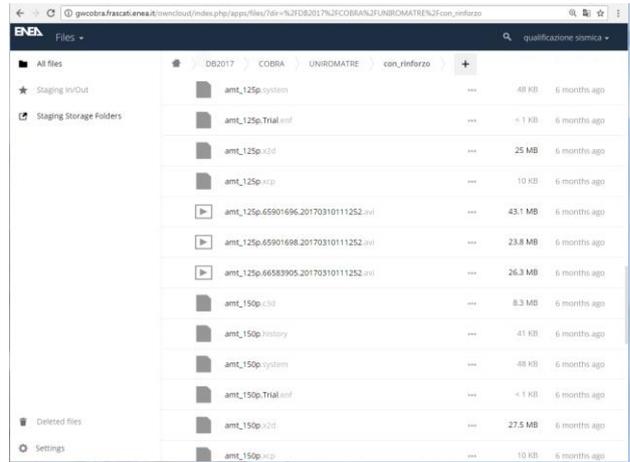


Fig. 4: OwnCloud web interface

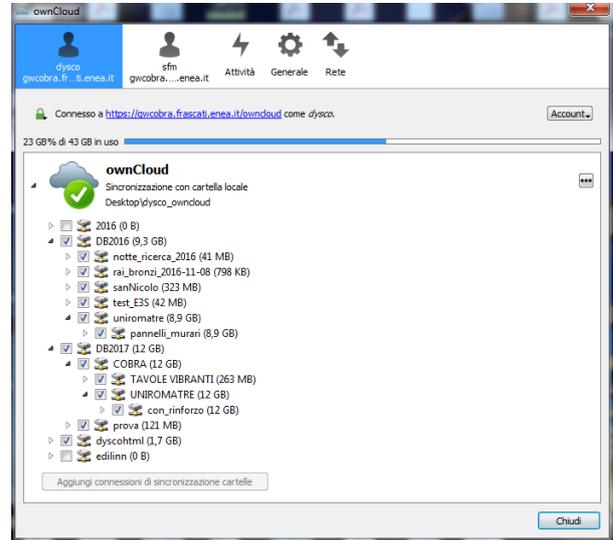


Fig. 5: OwnCloud client

The “insert/modify” section (See Fig. 6), only available within the laboratory LAN, was used by the user in charge of the test to extract metadata from the C3D file, save them into “dyscodw” database and launch the java script for signals and videos streaming by the DataTurbine (DT) application.

The “view” section, accessible from WAN, allowed remote users to visualize, all the information related to each acquisition step after the end of the experimental campaign: the number and label of each marker, the frame number and the frame rate.

For each record, remote users can also visualize the position in a 3D space of all markers positioned on the tested structures, their number and the label associated to each one, with the possibility to select a specific marker to visualize in complete autonomy the X, Y, and Z components of its trajectory, as shown in Fig. 7.



Fig. 6: DySCo Logbook “Insert/modify” section

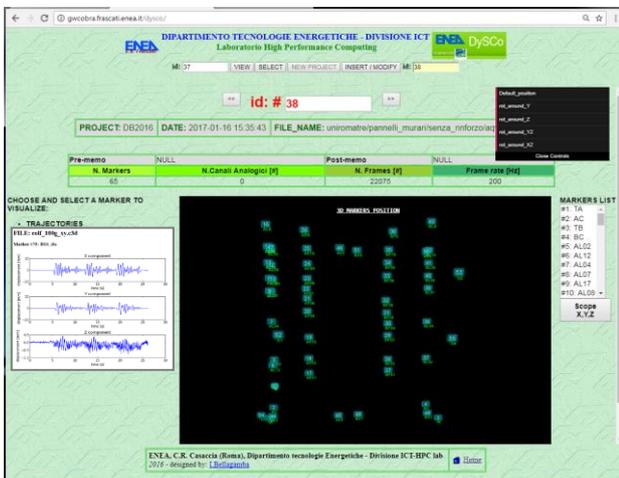


Fig. 7: DySCo Logbook “View” section

The seismic experiments were made of a sequence of tests with increasing seismic input intensity, until reaching a certain level of damage of the specimens.

To understand the dynamic behavior of the tested structures, a Finite Element Analysis (FEAs) was needed, mapping the stress and strain distribution and estimating their modal parameters. But this process is very time-consuming and the level of damage reached after each test step is often evaluated only by visual inspection.

The DataTurbine system (Fig. 8) can reduce time consuming by means of real time streaming functions and data managing. In addition to working with live data, the DT system can stream archived data as if they were live, for post-test data analysis and review. During the experimental campaign the data and the video from the test were streamed and shared in near real-time with remote project partners via RDV (Real Time Data Viewer) DataTurbine application (Fig. 9) and the damage level of the structures, reached at the end of each acquisition step, was used as the real seismic input for Finite Element Analysis.

FEA results were then compared with the experimental data for calibrating the material properties and the boundary conditions of the FE models.

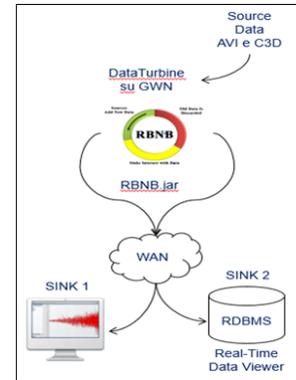


Fig. 8: RNB DataTurbine streaming process

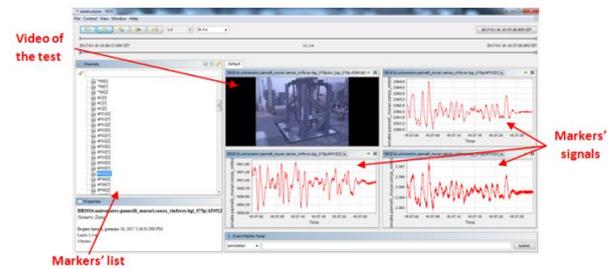


Fig. 9: RDV DataTurbine interface

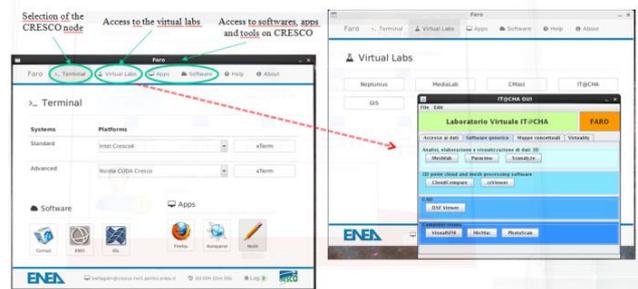


Fig. 10: Remote access to FE software

E3S “GPU Application Server” (GAS) provides an integrated graphical environment for the execution of many applications, included finite element analysis, on multiple hardware platforms, based on remotely accessible Graphic Processing Units.

In this way, remote skilled users have also the possibility to access the graphical tools installed on ENEAGRID IT infrastructure by an intuitive and user-friendly interface, named FARO2 (Fig. 10), using the computational resources offered by CRESCO HPC multi-core clusters, to run heavy jobs of scientific codes for structural modeling and numerical analysis.

III. CONCLUSIONS

The possibility to stream, save and store the experimental results, by means the heterogeneous functionalities of E3S architecture, allows remote skilled users to get in near real-time the results of each experimental test, to measure the damage of the structure and to calibrate the finite element model, independently from his geographical position.

The system is fully integrated in the existing data acquisition procedures and it takes advantage of all the reliability and performances of the preexisting ENEA AFS and GPFS file system.

This new approach of “sharing experiments”, performed by E3S architecture, gives the possibility to improve the research cooperation and dissemination in the field of seismic protection, reducing time-consuming during seismic experimental campaigns and at the same time it can be replaced for other researches on different application fields.

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