SACHER: Smart Architecture for Cultural Heritage in Emilia Romagna

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Abstract. The current Cultural Heritage management system lacks of ICT platforms for the management and integration of heterogeneous and fragmented data sources and interconnection between private and public subjects involved in the process. The SACHER project intends to fill this gap, working both on a technological level and on a business model level: firstly providing a platform based on an open-source distributed cloud-computing environment for the management of the complete data lifecycle related to cultural assets; moreover providing new models based on participatory design for Cultural Heritage data directed towards social entrepreneurship. This paper presents the first implementation of a system for managing data based on the 3D model of the cultural object, with a focus on the process for cultural assets management and the interface design for cultural services.

Keywords: 3D model · Cultural heritage · ICT platform · Service design

1 Introduction

The current Cultural Heritage management system lacks of ICT platforms that are able to manage the complete data lifecycle, integrate heterogeneous and fragmented data sources and interconnect the different private and public subjects involved.

The SACHER Project goal is to fill this gap, working both on a technological level and on a business model level. On the technological level, the SACHER Project will provide a platform capable of managing the complete data lifecycle associated with cultural assets based on an open-source, distributed cloud-computing environment. The platform will be based on the Active Digital Identity paradigm and will also take care of hardware and software integration between private and public partners. The SACHER platform will make collaborations between different public and private groups involved in Cultural Heritage management easier.

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On the business model level, SACHER will provide new models based on participatory design for Cultural Heritage data directed towards social entrepreneurship.

The SACHER platform will be tested on physical Cultural Heritage assets restoration projects in the Palazzo del Podestà area in collaboration with the Comune di Bologna.

The final purpose of the SACHER platform is not only to quickly produce a system that works in a real Cultural Heritage context and can be easily transferred to different cities, but also to create an environment of services and actors capable of enhancing the values of the Cultural Heritage business processes.

2 Management of Cultural Heritage

At present, the protection and enhancement of Cultural Heritage, particularly when dealing with significant monumental complexes, is supported by a series of digital devices not only used for reliable documentation, but also for carrying out in-depth scientific analysis on the work of art or monument and, further, to facilitate programmed maintenance activities.

Within this scope, the idea to use ICT platforms for managing data is not new anymore [1–3], but it becomes more and more necessary to design a platform providing support to the whole process related to cultural assets – actually missing – and, moreover, capable of gathering fragmented and incomplete data of different nature and from various sources. This fact has relevant implications for the efficiency of the platform in the long term and to assure an actual usability of the information system for the collection of all information about the cultural asset and the surviving of the data during the whole lifecycle.

In fact, when operating on Cultural Heritage, the amount of records resulting from the research phase is generally huge and heterogeneous [15]. As a matter of fact, a monument or building usually dates back to several centuries and it is necessary to carry out a very careful historical analysis before taking action with restoration or any other activity [11]: documents gathered include historical descriptions and drawings/paintings, graphic materials, analogue/digital pictures, existing technical and financial reports, construction site records filled out during previous interventions, etc. All the available information helps to reconstruct the evolution in time and consequently to design a correct approach to restoration and maintenance activities.

During the effective intervention phase, the documentation supplied by the operators is various and should be stored in a system which meets the requirements of easy sharing and storage, with reduced search times and preventing any possibility of errors or data loss. Furthermore, with reference to the importance of making the complete documentation available in real-time to experts and professionals in the field, the same applies to monitoring operations and in case of routine/emergency or planned preventative maintenance, as shown in Fig. 1.

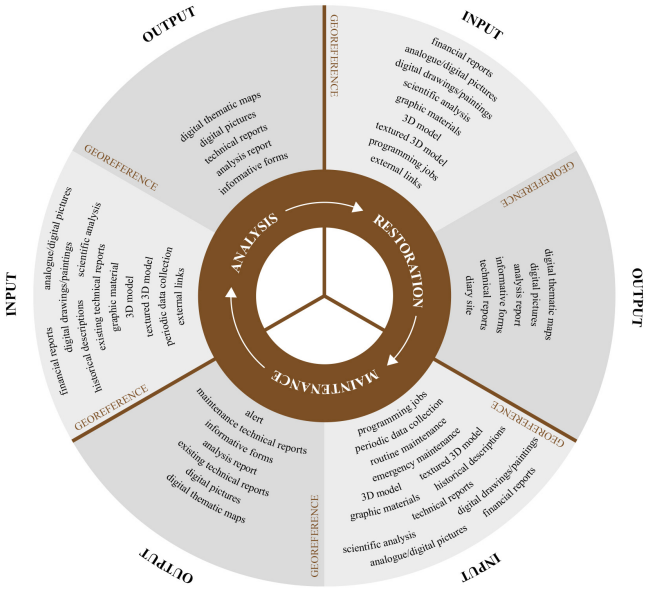

Fig. 1. Process of management of a cultural asset organised in three main phases: analysis of the current state of preservation and collection of existing documentation; restoration activities including intervention project, scientific analysis on materials and structures; maintenance and monitoring activities.

In recent decades the spread of digital and ICT tools in the various areas related to the cultural assets has supported, and now almost largely replaced, traditional methods of data-gathering, organization and management of information relating to Cultural Heritage. For this reason, there exist numerous studies aimed at developing software and web-based platforms for the collection of a multitude of heterogeneous data from the field of architecture and more particularly concerning the history of the restoration of monumental buildings, interesting from the historical and artistic point of view [13].

With regards to the management of Cultural Heritage data and IT solutions for documentation, since 2003 several national projects have been promoted with the collaboration of external partners and coordinated by the Italian Ministry of Culture. Among the various projects, ARTPAST[1] (*Applicazione informatica in Rete per la Tutela e Valorizzazione del Patrimonio culturale nelle aree sottoutilizzate*) had very fruitful outcomes. The project, coordinated by the Superintendence of Pisa and promoted by the General Directorate for Technological Innovation and Promotion, has been founded by CIPE for the years 2004–2008. Its purpose was to gather data for the SIGECweb (*Sistema Informativo Generale del Catalogo*) national database [12,14] and to digitize the heritage of historical-

[1] More information at ARTPAST - *Progetto per la digitalizzazione del Patrimonio*: http://www.artpast.iccd.beniculturali.it.

artistic and ethno-anthropological interest according to the standards laid down by the ICCD (*Istituto Centrale per il Catalogo e la Documentazione*) cataloguing system [7]. The project allowed an online consultation of databases by the Superintendence (nearly two millions forms containing photographs), in order to improve the control on works of art. Thanks to the collaboration between universities and ICT companies, two free and web-based software packages dedicated to the restoration have been implemented: ARISTOS [4] and SICAR [6].

As a result of multi-year studies, such as the RE.ARTE[2] project (*Restauri in Rete*), further contributions were given to the work started in previous years, both for data entry and user training. In this framework, the SICAR[3] Information System (*Sistema Informativo per la documentazione di Cantieri di Restauro*) has been implemented as an open-source platform paying specific attention to restoration [5]. The software has been developed by Liberologico as an implementation of an existing platform called Akira GIS Server [8,9], which was created specifically for the restoration of the Leaning Tower in Pisa.

The SICAR platform is a web-based GIS designed for managing the restoration work and characterized by the possibility to georeference vectors, rasters and alphanumeric documentation, from the earlier design phase until the restoration site phase and further intervention. It is a large archive based on forms relating different typologies of data: 2D geometric information (vector data) and alphanumeric ones (text documents, hypertext and semi-structured text in different categories, external data attached to system forms). Raster images can be the reference background (on an appropriate scale) on which it is possible to map 2D georeferenced polygons. The application is multi-user (with a lock system to avoid data inconsistency due to simultaneous modification by different users) and accessible via the web, both for data-entry and consultation by means of cross-searches.

The software has been officially adopted by MiBACT in 2008, becoming the official IT platform for the management of documentation concerning restoration sites, freely available for use by the ministerial employees in museum and public bodies. In 2011 its application has become mandatory for all the work promoted and financed by the Ministry, especially in case of intervention on protected objects, with the intention of computerizing procedures[4], simplifying the documentation delivery and sharing the process with the Superintendence, entrusted with collecting the available documentation on the restoration activities[5].

Recent updates of the SICAR software for its use in different domains are described in [20].

[2] See at http://www.sbappsae-pi.beniculturali.it/index.php?it/212/progetto-rearte.

[3] Details about the project at http://sicar.beniculturali.it:8080/website/.

[4] Italian legislative decree n. 82, 07/03/2005, "*Codice dell'amministrazione digitale*", in particular art. 42.

[5] The Circular n. 31, 22/12/2011 by the Directorate-General for Landscape, Fine Arts, Architecture and Contemporary Art provides for the compulsory use of the SICAR application for all restoration activities promoted and financed by the Ministry.

This paperless approach (also called "dematerialisation") is a common practice in Italian public administration since the introduction in 2005 of the requirement of a progressive increase in the computerized document management within the public administration and the replacement of traditional media for the administrative documentation in favour of IT documents. According to national regulations, this objective has been included as a matter of priority in recent strategies designed for gradual elimination of the paper, through the digitization of processes, towards a complete use of digital media for storage of written sources. The goal of dematerialisation in the restoration process is twofold: on one hand to avoid – or significantly reduce – the creation of new paper documents necessary by current procedures; on the other hand, to digitize the existing paper documents in the archives, replacing them with appropriate IT records. The main advantages are saving money and storage space, speed up sharing information and data, besides reducing the environmental impact.

2.1 3D Web Platforms for CH

Recently, thanks to further research in the domain, advanced novel solutions can include a detailed 3D model in latest-generation web-based information systems, providing additional and reliable information on the current state of preservation of the cultural object before restoration and on its possible modification during/after the restoration activity.

Many online platforms such as Sketckfab[6] or ARIADNE[7] allow community users to upload 3D digital contents for visualisation and web-based widespread dissemination.

Lately, it is increasingly common that researchers develop specific tools for information analysis and sharing results in Cultural Heritage. An example of this is CHER-Ob[8] (CULTURAL HERITAGE-Object) [19], an open source platform developed by the Computer Graphics Group of Yale University, which was tested on a section of the case study serving as a physical test of the SACHER project, the Palazzo del Podestà in the city centre of Bologna (Fig. 2). The system allows easy annotation on the model on the basis of some categories related to documentation, materials and analysis with possible upload of photographs and report generation of the collected material; however, heavy 3D models are not supported under the standard configuration, which can be an issue when dealing with complex architectures. More flexible platforms have been created for publishing high-resolution 3D contents with smart user interface [18] and in the latest times these have been used as web-based viewer by restorers with excel-

[6] Sketchfab - Your 3D content online and in VR: https://sketchfab.com/.
[7] ARIADNE - Visual media service: http://visual.ariadne-infrastructure.eu/.
[8] CHER-Ob: An Open Source Platform for Shared Analysis in Cultural Heritage Research, Computer Graphics Group, Yale University: http://graphics.cs.yale.edu/site/cher-ob-open-source-platform-shared-analysis-cultural-heritage-research.

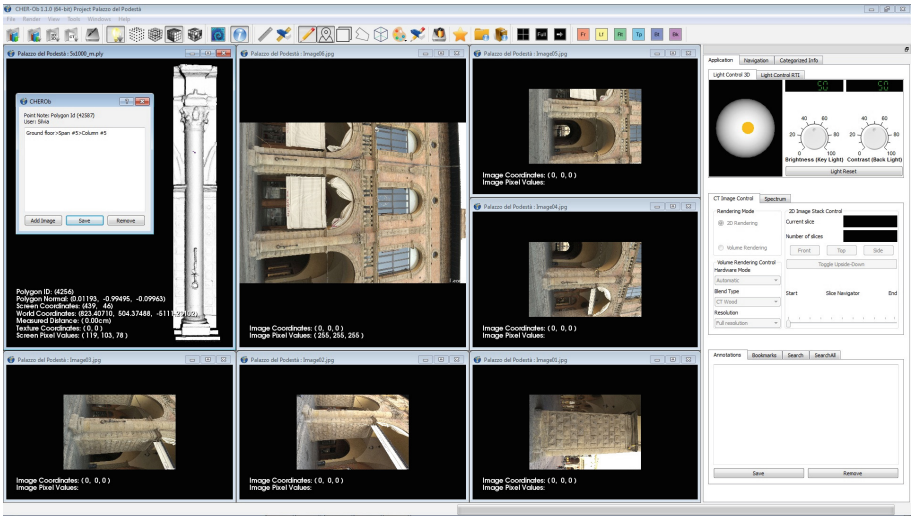

Fig. 2. The 3D model of the porticoed ground floor of the Palazzo del Podestà (5th column) and some reference pictures inside the CHER-Ob platform.

lent results for the Information System of the Neptune Fountain in Bologna[9], on the occasion of its recent restoration (started in 2016 and still in progress).

In this sense, web-based ICT systems can offer increasingly updated tools for the Cultural Heritage management, mainly for querying and storing work site documentation, but also for integrating public and private archives, connecting professionals to public bodies in a quicker and easier way and, if available, providing a smart 3D navigation system, always accessible to the users via the Internet. This results in a significant simplification in managing, and the number of domains where those applications can be profitably used is increasingly broad.

Since one of the objective of the SACHER project consists also in an active, widespread and free fruition by users, an open-source and distributed cloud-computing environment is considered the most appropriate tool for the SACHER platform.

The definition of operational protocols about cultural assets with an in-depth study on the process of the Cultural Heritage management – still an ongoing research activity – will provide a suitable data modelling in order to define data requirements needed to efficiently support activities and the information system. The analysis work done so far has involved academics, ICT experts, public bodies and final users working in this field. This useful collaboration provided suggestions and information on the ongoing project.

[9] Il Nettuno di Bologna. Il Sistema Informativo del restauro (Visual Computing Lab, ISTI - CNR): http://vcg.isti.cnr.it/activities/nettuno/.

3 User Interface Design for Cultural Heritage

Designing user interface services in the domain of Cultural Heritage is a hot issue in the current debate on Information Technologies, that more and more frequently generates new application dynamics to support the relationship between people and Heritage.

The SACHER project is based on the use of a textured 3D digital model as operational heart of a system that connects data pertaining to different disciplines. Therefore, the three-dimensional model represents the mean through which professionals in the sector can access and retrieve multidisciplinary information shared in a joint database and uploaded in a chronological order. The core concept for SACHER is the visualization and usability of contents and information thanks to an interactive exploration of the cultural object, linking data directly to the 3D model.

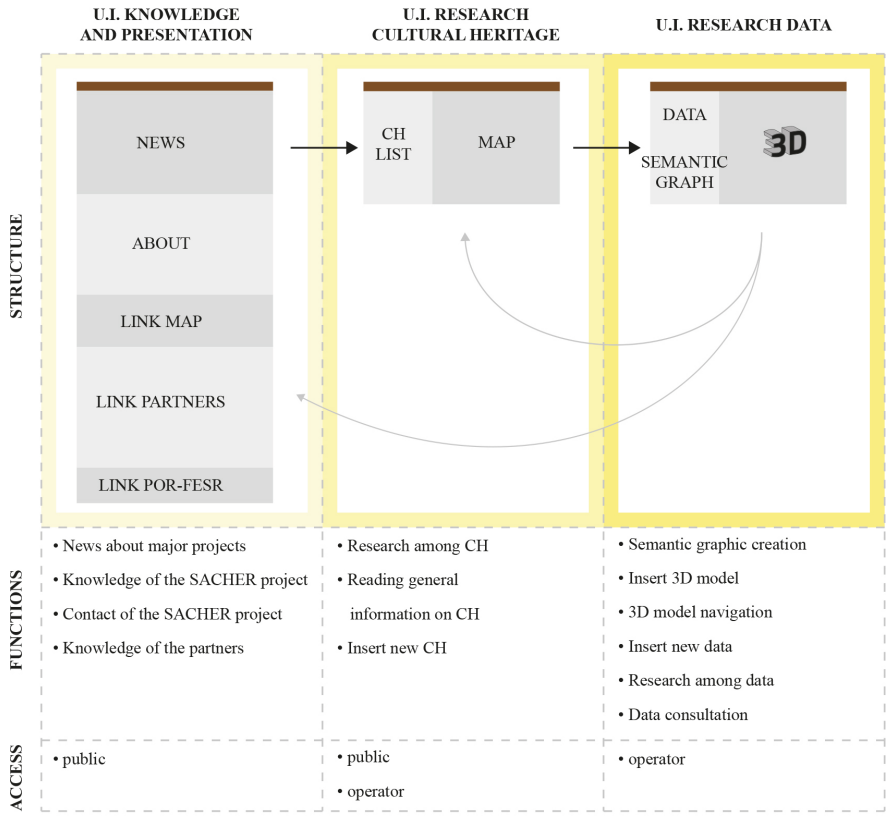

Fig. 3. SACHER platform, navigation: interfaces, levels of access and hierarchy.

On the basis of this idea, the development of the SACHER user interface exploits the 3D model and integrate three different design layers:

- the workflow of model of interaction between the users and the system;
- the organisation of the space of the interface with respect to the different tasks the users can perform;
- the graphics style of the interface.

In the SACHER platform, navigation is marked by three interfaces, with three different levels of access and hierarchy (Fig. 3):

- UI for introduction and presentation;
- UI for Cultural Heritage catalogue search;
- UI for information retrieval and data entry.

The first user interface (Fig. 4) is accessible to any user, and has the function of presenting and providing general information about the SACHER project, its partners' contacts, and a slideshow. The slideshow plays a relevant role in the platform, since it showcases the most important projects managed by SACHER, and it promotes the companies and professionals who work there.

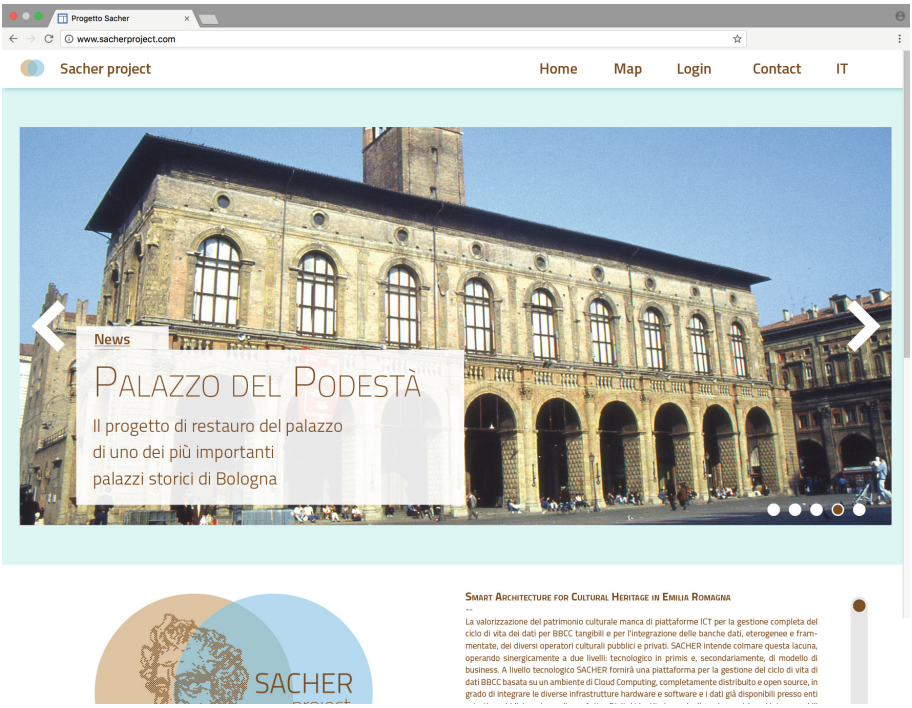

Fig. 4. UI for introduction and presentation.

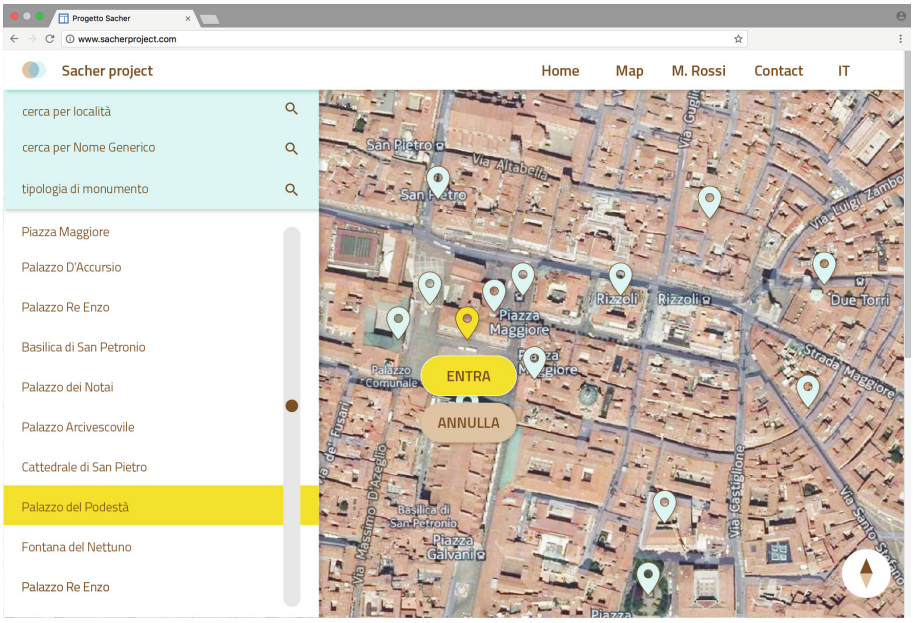

Fig. 5. UI for Cultural Heritage catalogue search.

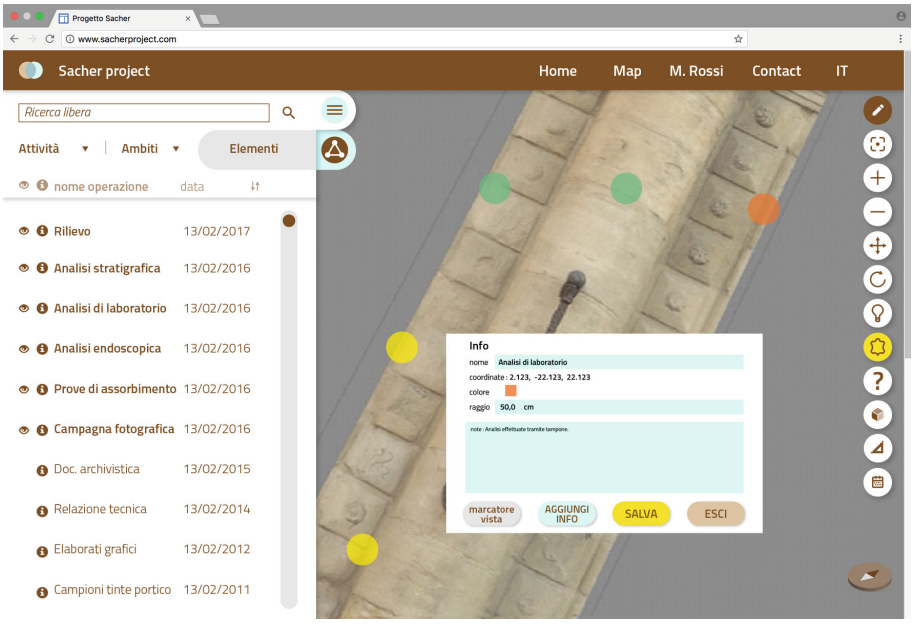

Fig. 6. UI for information retrieval and data entry.

Through this page, access is granted to the Cultural Heritage catalogue search interface (Fig. 5), where the SACHER Cultural Heritage catalogue can be explored through the search field or through navigation on an interactive map.

If the user level allows it, new Cultural Heritage items can also be registered. By selecting a specific item on the map, its presentation window can be opened. Through this window, access to the data management page of the item will be available (Fig. 6).

The professionals' work is focused mainly on the last UI, for information retrieval as well as data entry. This page shows a 3D model of the Cultural Heritage item, and its division into semantic areas. Beside the model, a graph that reflects the semantic distribution of the item can be used as guidance. Data can be consulted by navigating the 3D model, and isolating the single elements of interest.

If the user level allows it, it is possible to enter new data, indicating the relevant position on the 3D model, and attaching pictures or other documents. The windows that allow these operations are designed to save time, and to prevent users from becoming disoriented during interactions with the 3D model. The graphic style of the interface is inspired by the "Material Design" guidelines developed by Google, to improve usage and effectiveness of the digital tools, and to ensure compatibility on whichever device is used to access the platform. The colours are part of the coordinated image of SACHER, and due care has been used to avoid altering the perception of the 3D textures.

4 System Prototype

As previously suggested by Cucchiara et al. [10], the goal of this system is to bridge the gap between two different worlds, multimedia technologies and the arts, which can benefit from each other contributions. We plan to bridge this gap by creating a reusable, practical and open-source tool to manage restoration processes of Cultural Heritage assets with the clear intention of building a common and shared work methodology for the operators of both fields.

For this project we decided to rely only on open-source software tools. The main reason is to avoid vendor lock-in and to create a system that is completely independent from proprietary tools and formats and that can be easily adopted by anyone. A secondary but still very important aspect to consider is the cost reduction due to lack of software licenses needed to run open-source software.

We propose an architecture based on a web platform, which is easily accessible and does not require the users to install any kind of technical 3D modeling software to visualize the models.

The prototype of the system is based on a web platform called "eXo Platform", which is an open-source social collaboration software aimed at the creation of corporate intranets. Out of the box this platform provides everything that is needed to run a corporate social network, with features such as wikis, forums, calendars, documents management and private spaces.

The eXo platform is based on J2EE (Java2 Enterprise Edition), the portlet technology and on the GateIn portal manager. The platform is able to run on Tomcat or JBoss, two well known web application servers. The platform data is managed through the Java JCR API (Java Content Repository), an API that allows access to data repositories in a uniform manner, hiding the actual storage strategy. eXo Platform requires a database in order to work properly but is not tied to a specific RDBMS, in its default configuration it uses HSQLDB, a DBMS engine written in Java that is also able to use the filesystem to store the data and does not require a server application.

The strength of the eXo platform lies in its customization capabilities and in this project the platform has been widely customized to be able to host all the data needed to manage many Cultural Heritage restoration projects. By default, the website is accessible only to registered users, so a public homepage with "Login" and "Register" buttons has been added, in order to allow new users to request access to the platform. By logging in a user is able to browse the social area of the platform which shows the latest activities from the user's connections in a dashboard, as shown in Fig. 7.

The most interesting and useful feature offered by the eXo platform is called "Spaces". A space is a private area of the website in which subscribed users are able to share documents, wikis, forums and calendar events. In this project the concept of a space has been used to create private areas dedicated to different restoration projects, each of them with its own models and documents, such as images, technical reports and analysis, etc. In Fig. 8 the private document area reserved for a space is shown. The documents uploaded in this section are not available to those users who are not part of the space.

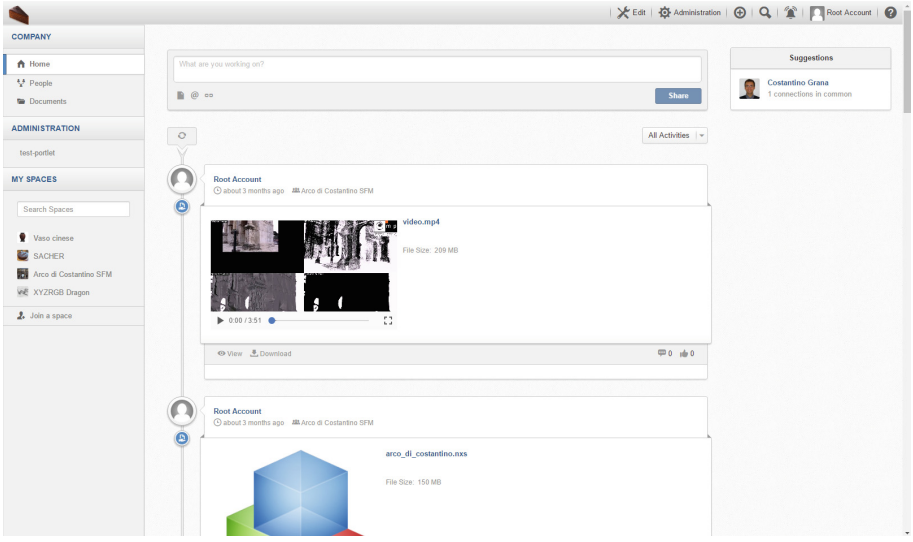

Fig. 7. eXo platform main social dashboard.

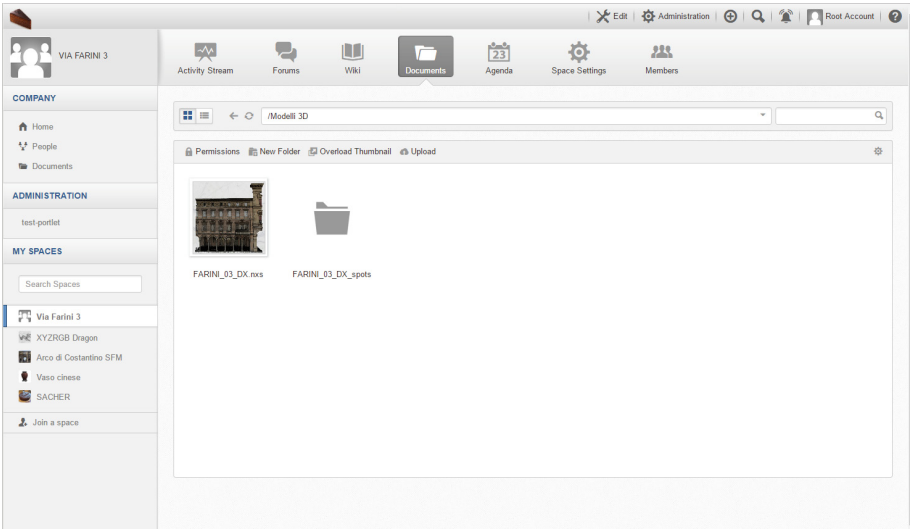

Fig. 8. The document area inside a private space, in this case called "Via Farini 3".

The main custom feature added to the platform concerns the 3D models visualization. Since the eXo platform provides an extensible mechanism to display specific file types in the browser, such an extension has been created based on a visualizer called 3DHOP (3D Heritage Online Presenter) [17]. 3DHOP is an open-source 3D model visualizer created by CNR (Consiglio Nazionale delle Ricerche) specifically designed to show Cultural Heritage 3D models in a web browser. It has been completely developed in Javascript and is ready to be used and integrated in a website.

3DHOP is able to show 3D models in the well known PLY format and also provides all the tools needed to take advantage of a different format called Nexus [16], created by the 3DHOP developers, which allows for fluid download and visualization of models of sizes ranging from a few kilobytes to a few gigabytes.

The Nexus format provides a multi-resolution representation of the model, allowing for a selective download of the 3D data through the HTTP protocol using the "range" parameter used to download only the parts of the model that are needed.

The 3DHOP visualizer capabilities have been extended in order to provide an annotation feature for the final user, allowing him to associate a point on the model, called "spot", to any kind of data uploaded on the server. All the spots are visible on the models as semi-transparent blue spheres and by clicking on them the user can edit the spot's properties, deleting it, changing its name or its size. In Fig. 9 is shown an example of an editing popup. Each spot is associated with a folder in the space's private documents area in which all the files associated with the spot can be stored. The folder is accessible directly from the spot's editing popup by clicking on a link, an example of such a folder is shown in Fig. 10.

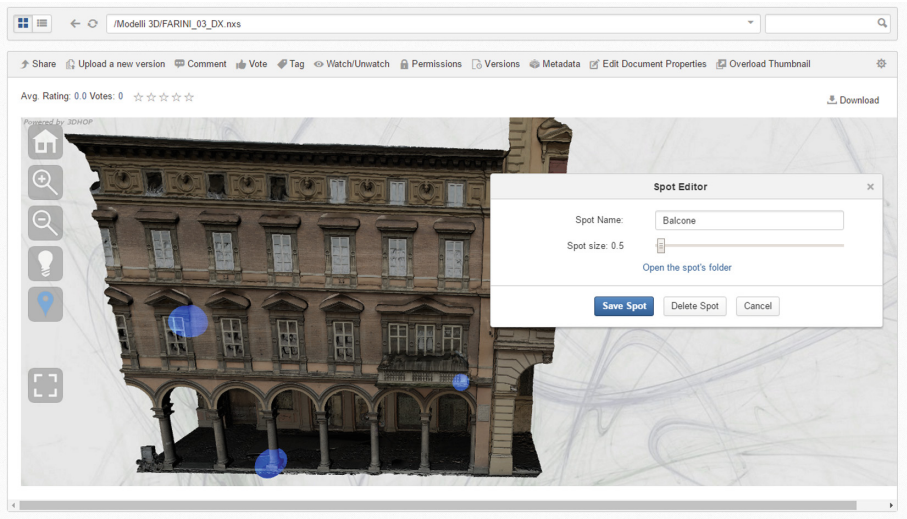

Fig. 9. The annotation editing popup. The user has the possibility to delete the spot or to change some of its parameters, such as its name or size. (Color figure online)

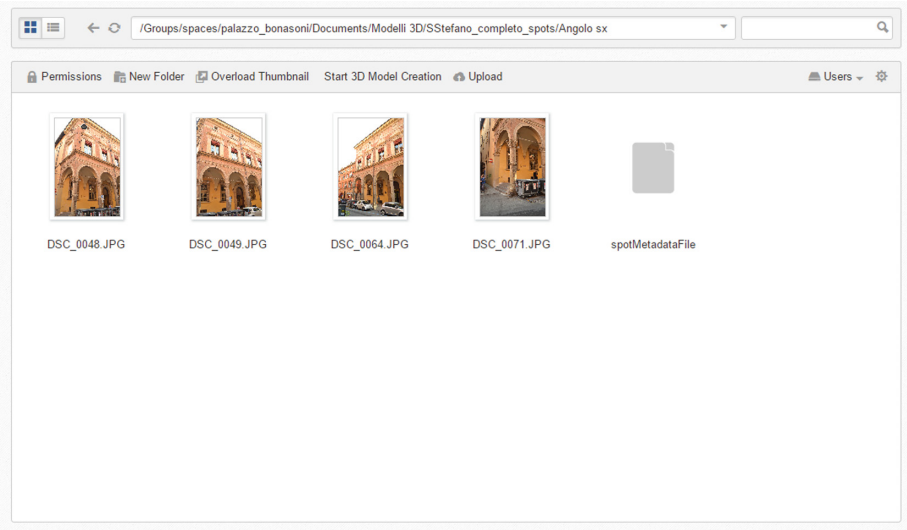

Fig. 10. The folder associated with a spot may contain images, documents and other data. The folder hierarchy can be extended based on the need of each restoration project.

The annotation feature is possible by means of a REST service integrated with the eXo platform which manages all the annotations stored in the JCR database and provides a special download method that supports the HTTP "range" parameter. The REST service is also accessible from other clients, not only by the eXo platform users, making the annotations' data also available to other applications.

This platform has been tested on a dedicated server with a 6-core CPU, 16 GB RAM and 150 GB of storage running Ubuntu 16.04 LTS.

5 Conclusions

In this paper we presented a brief overview of the existing systems for Cultural Heritage management, then illustrating the SACHER project, a platform designed to better manage CH restoration processes. At this stage we are still conducting a feasibility study using the prototype described earlier; in the near future we plan to improve our system providing a more customizable interface and by expanding the annotation capabilities of 3DHOP.

Acknowledgments. This project is partially funded by the SACHER project of the Emilia Romagna region in collaboration with the Municipality of Bologna. *SACHER: Smart Architecture for Cultural Heritage in Emilia Romagna. Piattaforma Innovativa di gestione dei BBCC tangibili per l'Industria Culturale e Creativa*; Acronym: SACHER; CUP Project No: J32I16000120009; POR-FESR 2014–2020, Axis 1, Action 1.2.2; Period: 01/04/2016-31/03/2018; Scientific Project Manager: Rebecca Montanari (CIRI-ICT); Coordinator: CIRI ICT (Alma Mater Studiorum Università di Bologna); Partners: Softech-ICT (Università degli Studi di Modena e Reggio Emilia), Centuria Agenzia per l'Innovazione della Romagna; Other participants: Comune di Bologna, Imola Informatica s.p.a., Engineering Ingegneria Informatica s.p.a., Leonardo s.r.l.

References

1. Apollonio, F.I., Baldissini, S., Beltramini, G., Borgherini, M.M., Clini, P., Gaiani, M., Palestini, C., Sacchi, L., et al.: I geo-modelli per la PALLADIO Library: un archivio condiviso e in divenire. Disegnare Idee Immagini **47**, 46–59 (2013)
2. Apollonio, F.I., Corsi, C., Gaiani, M., Baldissini, S.: An integrated 3D geodatabase for palladio's work. Int. J. Architect. Comput. **8**(2), 111–133 (2010)
3. Apollonio, F.I., Gaiani, M., Benedetti, B.: 3D reality-based artefact models for the management of archaeological sites using 3D GIS: a framework starting from the case study of the Pompeii Archaeological area. J. Archaeol. Sci. **39**(5), 1271–1287 (2012)
4. Baracchini, C., Boscaino, I., Levi, D., Maffei, A.: ARISTOS: archivio informatico per la storia della tutela delle opere storico artistiche. Bollettino d'informazioni del centro Ricerche Informatiche per i Beni Culturali **12**(2), 57–81 (2002)
5. Baracchini, C., Fabiani, F., Grilli, R., Vecchi, A.: SICaR w/b, un Sistema Informativo per la progettazione, il monitoraggio e la condivisione delle attività di restauro: verso un network della conservazione. In: Atti del Convegno di Studi Scienza e Patrimonio Culturale nel Mediterraneo. Diagnostica e conservazione: esperienze e proposte per una Carta del Rischio, pp. 507–519 (2009)

6. Baracchini, C., Lanari, P., Scopigno, R., Tecchia, F., Vecchi, A.: SICAR: geographic information system for the documentation of restoration analysis and intervention. In: Proceedings of SPIE 5146, Optical Metrology for Arts and Multimedia, vol. 13, pp. 149–160 (2003). doi:10.1117/12.501505
7. Berardi, E., Marsicola, C., Sanzi Di Mino, M.R.: L'utilizzo della digitalizzazione nell'ICCD: stato dell'arte e prospettive. DigItalia **1**, 97–100 (2005)
8. Capponi, G., Lanari, P., Lodola, S., Magnatti, C., Parrini, U., Vecchi, A., Vedovello, S., Veniale, F.: Il software Akira GIS Server - un'applicazione nella mappatura dei materiali costitutivi e dello stato di degrado della Torre di Pisa. Bollettino del Centro di Ricerche Informatiche per i Beni Culturali **5**, 115–126 (2000)
9. Capponi, G., Vedovello, S., Vecchi, A.: Realizzazione del sistema informatico Akira GIS Server. In: Il restauro della Torre di Pisa: un cantiere di progetto per la conservazione delle superfici, pp. 46–53 (2001)
10. Cucchiara, R., Grana, C., Borghesani, D., Agosti, M., Bagdanov, A.D.: Multimedia for cultural heritage: key issues. In: Grana, C., Cucchiara, R. (eds.) MM4CH 2011. CCIS, vol. 247, pp. 206–216. Springer, Heidelberg (2012). doi:10.1007/978-3-642-27978-2_18
11. De Luca, L., Busarayat, C., Stefani, C., Renaudin, N., Florenzano, M., Véron, P.: An iconography-based modeling approach for the spatio-temporal analysis of architectural heritage. In: SMI Conference 2010, pp. 78–89. IEEE (2010)
12. Desiderio, M.L., Mancinelli, M.L., Negri, A., Plances, E., Saladini, L.: Il SIGECweb nella prospettiva del catalogo nazionale dei beni culturali. DigItalia **1**, 69–82 (2013)
13. Jiménez Fernández-Palacios, B., Remondino, F., Stefani, C., Lombardo, J., De Luca, L.: Web visualization of complex reality-based 3D models with NUBES. In: Digital Heritage International Congress (DigitalHeritage), vol. 1, pp. 701–704. IEEE (2013)
14. Mancinelli, M.L.: Sistema informativo generale del catalogo: nuovi strumenti per la gestione integrata delle conoscenze sui beni archeologici. Archeologia e Calcolatori **15**, 115–128 (2004)
15. Meyer, E., Grussenmeyer, P., Perrin, J.P., Durand, A., Drap, P.: A virtual research environment for archaeological data management, visualization and documentation. In: 35e Conférence du CAA Layers of Perception, Advanced Technological Means to Illuminate Our Past, pp. 1–6 (2007)
16. Ponchio, F., Dellepiane, M.: Multiresolution and fast decompression for optimal web-based rendering. Graph. Models **88**, 1–11 (2016)
17. Potenziani, M., Callieri, M., Dellepiane, M., Corsini, M., Ponchio, F., Scopigno, R.: 3DHOP: 3D heritage online presenter. Comput. Graph. **52**, 129–141 (2015)
18. Potenziani, M., Callieri, M., Dellepiane, M., Corsini, M., Ponchio, F., Scopigno, R.: 3DHOP: una piattaforma flessibile per la pubblicazione e visualizzazione su Web dei risultati di digitalizzazioni 3D. Archeomatica 6(4) (2015)
19. Shi, W., Kotoula, E., Akoglu, K., Yang, Y., Rushmeier, H.: CHER-Ob: a tool for shared analysis in cultural heritage. In: EUROGRAPHICS Workshop on Graphics and Cultural Heritage (2016)
20. Siotto, E., Baracchini, C., Santamaria, U., Scopigno, R.: Sperimentazione del Sistema Ministeriale SICaR w/b per la gestione e la consultazione informatizzata dei dati sulla policromia. Archeologia e Calcolatori **27**, 131–151 (2016)