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Original article

# A 3D-centered information system for the documentation of a complex restoration intervention

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ABSTRACT

Restoration is becoming a quite complex process: a large number of internal and external variables co-exist and may impair it. Among these, the large number of professionals involved and the huge amount of documentation produced can heavily affect the quality of the intervention as well as the possibility to have systemic and informed interventions in the future. In particular, a standardized method for storing restoration data and accessing them is still lacking, and the use of new technologies is still limited and/or not scalable. The paper describes the process of designing and testing an information system (IS) based on three-dimensional (3D) data, aimed to support the restoration of Neptune's Fountain in Bologna. In preparation of the restoration, a major effort was carried out to design and implement a web-based IS able to host all of the data produced, to allow the conservation-restoration specialists to interact on-site with an accurate 3D representation of the elements of the fountain, and to directly reference all information and data produced on the geometry of the model. The paper focuses on the challenges and adopted solutions related to the use of 3D models and the data mapping on 3D surfaces in the context of restoration documentation. Highly detailed visualizations of the models, easy navigation, and usable functionalities to add information directly on the 3D model have been achieved by extending the available solutions and by implementing new mechanisms to overcome the limitations of WebGL and remote rendering. Neptune IS' development has been extensively experimented in a real context of use. Results and knowledge from the experimentation currently represents the basis for evolving Neptune IS into a possible generic and flexible platform for documentation management in the field of restoration and related methodologies.



## 1. Research aim

Documentation organization and accessibility are important tasks in all restoration processes. This work aims to explore a new methodology for the organization, management and access of all the data produced during complex restoration processes supported by a 3D-based information system (IS). The system exploits the 3D model of the object under restoration as the pivotal element and the central reference space for the whole work. The paper then discusses the results coming from a real context experimentation of the IS in a restoration project and describes the future development of the system based on the results coming from the experimentation.

Currently, the IS permits storing data in real time, by mapping them over a high-fidelity, digital 3D model of the artwork and inserting them in the system database. The IS relies on web standards and employs web technologies (HTML5 and WebGL) so that it can be used from everywhere and by everyone via the Internet. The system supports not only the online insertion of information, but also its consultation and preservation.

## 2. Introduction

Cultural heritage (CH) restoration is an extremely complex activity since it involves the expertise of several professional figures (restorers, architects/engineers, art historians, chemists,

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photographers), who produce a massive amount of documentation. All of the temporal steps of the restoration process (analysis, study, intervention) need to be documented in detail. The accessibility of these data is crucial both for a specific restoration as well as for future actions. The same data is crucial for the maintenance activities.

Many different approaches have been proposed and used to encode, store and manage restoration documentation (see Section 3). Most of them are based on two-dimensional (2D) approaches where the information is mapped on several 2D projections (images or drawings) and the documentation is indexed or represented by the means of those representations. However, the use of a digital 3D representation would introduce significant improvements, as it would allow for the inclusion of a comprehensive and holistic perspective, which is inherent to any architecture and sculpted monument. The shift from the 2D to the 3D based model of interaction would overcome the limits of merely text-based descriptions of the already available information and documentation of the monument, which usually provide indirect or unclear links to the other documentation.

Due to the reduction of 3D digitization costs and the progressive democratization of related technologies, the production of a 3D model is nowadays becoming a standard action in many restoration projects. Nevertheless, the potential of 3D models has not yet been completely exploited in restoration as the basis for the implementation of a reliable data documentation pipeline and as an interface to easily access them [1]. The restoration of Neptune's Fountain in Bologna (Italy) has represented the occasion to conduct a concrete case study to implement this hypothesis.

The paper discusses the result of a process of the design and implementation of a web-based IS, centered on a high-quality, 3D digital representation of the artwork that becomes the pivotal element of interaction to store and consult new and previous restoration data.

This model of interaction introduces a new approach to the design of the ISs for the consultation and production of information in restoration where data can be stored and annotated on an intuitive 3D web-based interface accessible to the entire restoration staff.

The IS presents many innovative features:

- it is built on top of a semantically-organized and high-resolution digital 3D representation of the monument to be restored;
- all system functionalities are showed to the users using standard web technologies so that the system is accessed and edited using only a browser on desktops, laptops or tablets devices;
- users can easily navigate the digital 3D model;
- all documents and data are inserted in the system with a simple interactive Graphic User Interface (GUI) and associated to the 3D model;
- the 3D model may also be used to support the online production of technical drawings depicting the conservation status and the relative intervention.

A database is used to store and access the structured and 3D annotated data and to solve user queries. The system supports all phases of the restoration process (preliminary visual analysis; uploading documents and results of scientific analysis; production of observation and intervention mappings; and data retrieval).

The paper describes the system specifications and its features by referring to the specific case study of Neptune's Fountain. However, most of its components might be easily reused to support the restoration of diverse art typologies. The early validation conducted with experts and restorers of the ISCR largely proved the effectiveness of the proposed approach.

## 3. State of the art

Over the last decades, the application of digital technologies to the production and management of CH-related data has progressively been replacing traditional methods of data gathering, organization and management of information.

One of the main directions of work has been the exploitation of the same principle used by Geographical information systems (GIS), where layers of data are spatially associated to a territorial area. This GIS approach has been used to characterize the surface of the artwork, by linking available knowledge (e.g. all the results of the scientific investigative analysis) to specific areas defined over the artwork surface.

An example of a system following this approach is SICaR Web [2,3], a web-based system for the management of the information gathered during restoration planning and the intervention phases (Fig. 1a). The data available are mapped and referenced on a 2D representation of the artwork. SICaR allows for the linking of all the data gathered during the phases of the analysis and the restoration process, e.g.: raster images, documents in TXT format, hypertext (HTML) or semi-structured text (XML).

As in any other GIS platform, SICaR offers features to cross-compare different layers (overlay function) and to support the analysis of the data.

The GIS approach (data mapped over 2D projection spaces) might be perceived as a limitation for some CH applications. GIS technology was originally developed to represent "2D 1/2 models" (i.e. terrain models) and is a natural choice to represent 2D domains (e.g. painted surfaces, or facades of buildings which can be easily projected on a plane).

More recently, GIS systems have been extended by supporting also the direct representation of 3D domains. For an example, please see the work done by Dell'Unto et al. [4] in the field of archaeology. This work extends the capability of the system and its flexibility of use from using projection planes to drawing regions directly over the 3D surface of the artwork. A more systematic approach to the use of 3D GIS was proposed by Campanaro et al. [5] through the creation and management of 3D GIS thematic layers to record and analyze specific aspects related to the state of conservation. However, its application is essentially limited to architectural spaces, where the surfaces of interest are essentially nearly planar. Additionally, built heritage is a field where conservation and management methods are more standardized [6]. Further experiments on archeological data are reported in De Reu et al. [7] and are referred to the creation of GIS-like annotations.

Moreover, the complexity of use and the time required to produce the documentation are the most critical and limiting factors of the GIS-based approach. GIS systems are usually very broad and complex in terms of functionalities as they are designed to support a wide range of different application domains. A restorer could use a very small fraction of the available features at the cost of a quite steep learning curve. Moreover, while web GIS systems are becoming more popular, they are still quite limited in terms of features, and hard to handle.

In a few cases, restorers have directly used a 3D modeling system (e.g. AutoCAD) to import 3D models and characterize the surface of the represented model. Again, this approach requires the restorer to be able to master a (complex) CAD modeling tool, whose features are not specialized. Moreover, the management of the very complex and high-resolution models available in CH can be complicated. An example can be found in the work done at ISCR when managing the drafting related to the very recent restoration of the Coliseum in Rome (see Fig. 1b).

Other systems also use a web platform to produce drawings or characterizations over a 2D raster image. An example is Modus Operandi, a documentation system developed by Culturanuova s.r.l.

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