Semantic integration in cultural heritage 3D modeling for multi-dimension access to historical knowledge

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***Abstract*—Rapid advances in digital technologies in the last twenty years have offered cultural heritage new possibilities in conservation and promotion. 3D digitization has especially become more and more affordable and efficient. This leads to massive digitization projects and increasing amount of cultural heritage digital data. As an engineering team working on industrial techniques for reverse engineering, we are deeply affected by this effect. In this paper we propose a way to combine semantic information on top of the acquisition and modeling steps in order to manage heterogeneous historical data. We illustrate our approach with 3 related use cases at different levels of detail.**

Keywords*—*Industrial heritage, knowledge management, 3D modeling, information visualization, levels of detail.

I. Introduction

Considering the amount of existing 3D digitised models of cultural heritage objects, we need to combine their references. In this paper, our goal is to describe the process from mass digitisation to mass customisation of these historical witnesses. Indeed, modeling the context is a way to explore the objects through several aspects. Three main aspects are considered: temporal, spatial and thematic. Each aspect includes several levels of detail:

- The temporal dimension can be related to a short period of time (machinery production cycle), an intermediate period (machinery lifecycle in the factory) or even a long period (the whole lifecycle including the functioning period and its lifecycle as an heritage object).
- The spatial dimension can be related to both the geometric shape and the geographical area. Although a cultural heritage object can have no specific position (e.g. vehicles, steam engine or any generic technical object), it is linked to one or more geographical environments.
- The thematic dimension is not finite and can be related to many research domains: social, economics, mechanics, aesthetic, etc. This aspect is significant to understand different points of view on the object.

The main issues lay into the management of historical knowledge and the access to information. Our idea is to make connexion between the physical object and a knowledge database. This connexion allows identification of lacks of information, and cross navigation through the three aspects mentioned above. In addition, semantic keyword navigation is possible.

We will describe in section II the three cases that lead us to these considerations:

1) "Nantes1900" project focuses on industrial heritage through the case of a 100 years old scale model.
2) The case of "Halles Alstom", an industrial complex based in the harbour of Nantes from 1850 to 2001.
3) The last case is a transporter bridge that was present on the harbour area from 1903 to 1958.

Based on these three use cases of conservation and promotion of cultural and industrial heritage, we wanted to make connexions between the different pieces of information. Our goal is to gather the knowledge capitalized in these different projects. Combining both historical documents and produced knowledge (under the form of 3D models or written analysis) would allow researchers and broad public to explore different scales and dimensions of the different objects involved.

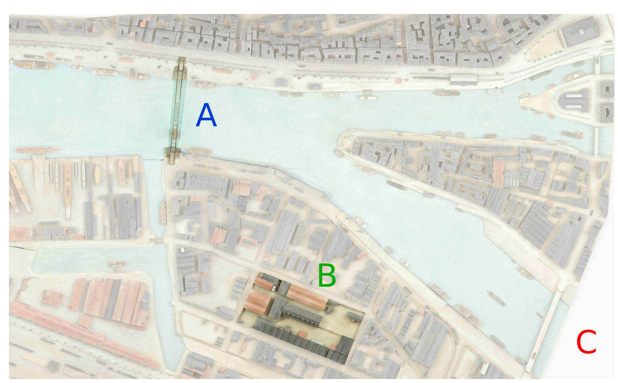


Fig. 1: Geographical positioning of the three use cases between 1899 and 1913: the global area represents a part of Nantes harbour (C), and the two other use cases are highlighted: Transporter bridge (A) and "Halles Alstom" (B).

In this paper we describe how we make connexions between the different objects, on the different aspects mentioned above (spatial, temporal, thematic). Finally we discuss the advantages and limits of our approach. The idea is to manage artifacts' physical representations (3D, dynamic simulations) based on available knowledge. This allow us to identify research hypothesis because we believe 3D reconstitutions should create at least as many questions as it answers.

II. Modeling heterogeneous historical documents

3D digitization has especially become more and more affordable and efficient. This leads to massive digitization projects and increasing amount of cultural heritage digital data [1] autre réfs . Every project in cultural heritage conservation and promotion we are involved into implies the creation of new historical material under the digital form. Many of these materials have implicit links: geography, time, thematics. Therefore, we want to manage these connexions to access information through different dimensions.

Three cases are used to support our approach:

a) "Nantes1900" project: focuses on industrial heritage through the case of a 100 years old scale model. This scale model is part of Nantes (France) history museum. In this project, we have a delimited spatial area which is the harbour of a city. We also have many heterogeneous historical documents related to hundreds of points of interest. The 3D model of the physical scale model comes from scanner digitization (Creaform HandyScan). It is composed of 100 million points. In addition, we gathered a corpus of 1000 historical documents (postal cards, archives documents, paints, photographies, books, etc.) and hundreds of notes written by historians. Based on this corpus, we created a knowledge database to handle these information.
The global level of detail is related to the city scale approximately between 1899 and 1920. The database stores information about many thematics related to industrial activity: social ("labour conditions in the early 1900's", people biographies), economics (companies' chronicle), technology (shipyards, steam engines), architecture and urbanism (urban network), etc.

b) "Halles Alstom": an industrial complex waiting for rehabilitation and based in the harbour of Nantes. This historical "object" is part of the scale model mentioned above. In this case, we have a specific historical analysis that lead to a monography (master thesis). We also have specific historical documents such as 3D models coming from photogrammetry (using Agisoft Photoscan). This analysis focuses on an area related to a factory scale, but with a broader time period (1850-2001). Compared to the Nantes1900 project, only some thematics are covered: technology (mechanics, materials), architecture and urbanism.

c) Nantes transporter bridge: that was present on the harbour area from 1903 to 1958. Based on historical and technical archives, we created a functional CAD 3D model. This 3D model can simulate the transporter bridge during its functioning cycle. On this object, the different dimensions taken into account are smaller: the geometry is related to a single industrial element, and the thematic dimensions focus on its technical and aesthetic aspect.

Our approach needs to be adaptative to different historical data (physic and semantic) acquisition processes. The main objective is to model information in order to combine the three dimensions represented on Fig. 2. 3D physical information is not attached to any thematic but to space and time. Our methodology allows to switch from mass digitization to mass customization of virtual artifacts. Virtual artifacts can be both physical or semantic/abstract representation about studied objects. They are composed of sub-parts of the main cube (Fig. 2).

III. Multi-dimension knowledge modeling

Section II have shown that each of our three historical use cases are a combination of the three axis of Fig. 2. We state here that every historical object can also be represented this way.

Therefore, we propose a methodology based on the creation of relationships between descriptive pages dedicated to cultural objects and these 3 axis. First, we create a descriptive page. This descriptive page is a classical historian's production composed of full text document with historical sources. Thus, this work is subjective so we aim to confront it to other ones. Based on the content, we link this page with other ones through the identification of common keywords. This linking step can be semi-automatic thanks to text mining techniques such as named entity recognition [2]. Then, we attach three variables for the positioning of the descriptive page in the Space-Time-Thematic cube. The thematic dimension can be deduced from the previous step of keywords identification. The spatial positioning can be divided into three parts :

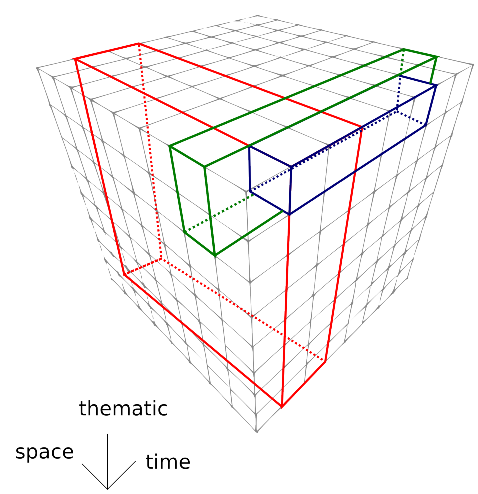


Fig. 2: Schematic representation of the Space-Time-Thematic cube. The three use cases are represented in different colors to illustrate the different dimensions: Nantes1900 in red, Halles Alstom in green and Transporter bridge in blue.

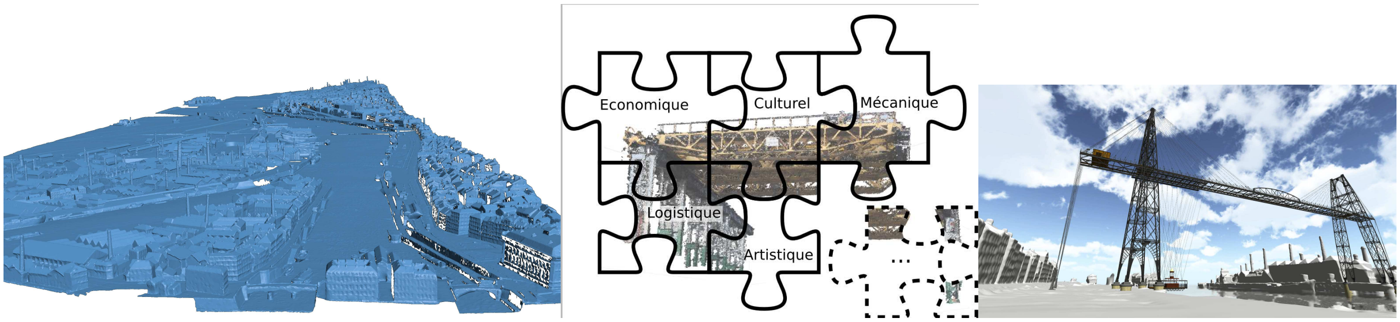


Fig. 3: Use cases' 3D models with different acquisition techniques : 3D scan, photogrammetry, and 3D reconstruction (CAD model).

1) Mandatory association between the descriptive page and geographic area(s). Whenever this kind of information is not avalaible, the information system has to highlight this page as incomplete. This would allow users to identify potential research axis.
2) Potential association between a 3D part and other spatial information (map, 3D part, etc.)
3) Potential association between descriptive page and 3D part (when available)

This methodology implies that every descriptive page can be represented on Fig. 2 by a group of blocks. Considering our three use cases, they gather a group of descriptive pages (blocks). On Fig. II, we represent 3 volumes corresponding to an average of all these blocks for each use case.

Actually, the highlight of the three use cases on Fig. II occurs only when a user query the system with related keywords. In fact, the 3 volumes are the image of a user's search for each use case. Once the user accesses a descriptive page, the system provides links according to neighbouring blocks and keywords cooccurences. This way, the user is able to navigate all around his first search. He can explore combined, dynamic 3D environments and semantic networks.

IV. Concrete application with use cases

A. Results of semantic integration for 3D cultural heritage examples

In order to illustrate our methodology described in section III, we present several descriptive pages for each of our three use cases and the way they connect in the system .

"Nantes1900": This project includes 3 specific descriptive pages: "Jean-Simon Voruz", a businessman who set up a foundry in 1850 on the "Halles Alstom" site, Nantes transporter bridge which is our third use case, "Ateliers et chantiers de Bretagne", one of the most important shipyard of Nantes in the beginning of the twentieth century.

"Halles Alstom": This study includes 2 descriptive pages: the "south wall", and the 1943 bombing on "Halles Alstom".

"Transporter Bridge": This project includes 2 descriptive pages: the windowed cabin (which was used to transport people across the river) and the category of cable-stayed bridges.

Fig. (schéma) represents an image of the whole proposed system simplified with the example of the 7 previously mentioned descriptive pages. Historical studies focus on specific subject leading to a particular research context. Such context is marked out with temporal, spatial and thematic boundaries. When the user selects a descriptive page, the system provides a set of connexions with other pages based on keywords cooccurences. Resulting network has spatial, temporal, thematic and semantic features according to the cube Fig. 2. In addition, some of the network's elements can be connected to 3D models. This model is a way to navigate between different levels of detail and dimensions.

In our example above, one possible query returns 3 descriptive pages ("1943 bombing on Halles Alstom","Halles Alstom" and "Nantes transporter bridge"). Then, the user can choose one of them (e.g. "Nantes transporter bridge"). Finally, the system provides all the related content (text analysis, historical sources and 3D models), and the context of the user selection. This context includes semantic linked pages ("windowed cabin", "cable-stayed bridges") and a spatio-temporal-thematic neighbourood. Neighbourhood criteria are defined by the user (e.g. "5 to 10 years" and/or "less than 500 meters").

B. Proposal of virtual reality based interface

We propose several solutions to explore this heterogeneous data. First, the user can navigate in the scene using bird view paradigm: it allows to visualize information through different points of view. He can also fast travel to another location by selecting a visible point on the model, the camera will travel in a direct line or hover above the destination, which can be useful to quickly explore points of interest.

The user can quickly see the details or move the camera on one of these items, he can also choose to highlight the

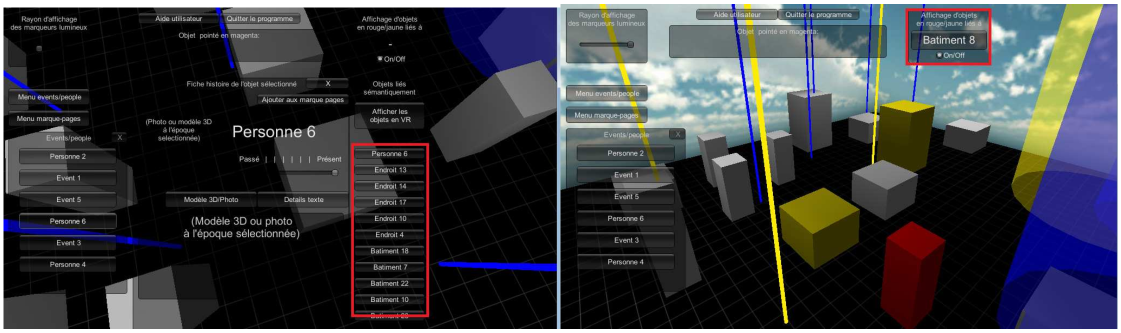


Fig. 4: Visualizing connections between items in the scene based on database information.

entire group on the 3D scene to quickly see the locations of items of interest.

Each historical sheet (Figure 4) can show the evolution of the item selected through time, the user can choose an era within the available data and check the details relevant to this age, it can be a different picture or a different description for example.

If we combine all these data types previously seen, the interface and the visualization can become messy and non-efficient. The solution would be to use filters and layers to show only what the historian is interested in at the moment. The first step is to create a numeric cursor to choose the radius where we display the luminous rays around the user, allowing to manage the number of semantic details. À partir d'un certain nombre de fiches, montrer l'intérêt que ça peut avoir pour naviguer entre les fiches. Par rapport à la section précédente, illustrer ce qu'on veut faire à la fin : exemple du proto 3D pilotée (Unity).

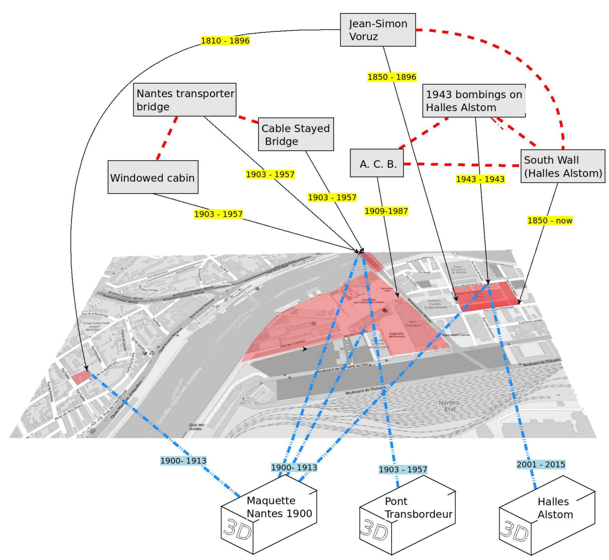
Scénario d'utilisation

V. Conclusion

Pistes actuelles d'amélioration : Semantically enriched 3D cultural heritage models [3]

Objective: in order to contextualise these cultural heritage objects

La 3D vient enrichir le tout



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