VIRTUAL 3D RECONSTRUCTION OF PLANS-RELIEFS FROM HISTORICAL DOCUMENT ANALYSIS FOR VALORISATION APPLICATIONS

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***Abstract*— The French collection of Plans-Reliefs, scale models of fortified towns, constitutes an awesome architectural heritage. Facing this patrimonial richness, many cities, represented on these plans-reliefs, would like to expose, develop and exploit this historical heritage. However, the fragility, the dimension of the supports and the exposure conditions makes this acquisition difficult. Thus, the creation and the exploitation of a virtual model constitute an interesting alternative. This paper presents a method exploiting historical documentary for the 3D semantic modelling and the valorisation of the virtual Plan-Relief of Verdun. The original Plan-Relief is currently enclosed in containers in Paris.**

***Index Terms*—Historical documents, 3D semantic model, method, scale models, valorization application**

I. INTRODUCTION

The French collection of Plans-Reliefs constitutes an awesome architectural heritage. These scale models of fortified towns were built under the reign of Louis XIV of France (Fig.1). From an initial collection of 260 plans-reliefs, only one hundred models are preserved. Most of them are exposed in the ”Invalides” museum in Paris and the others are in the museum ”Palais des Beaux-Arts” in Lille (France). Facing this patrimonial richness, many cities, represented on these plans-reliefs, would like to expose, develop and exploit this historical heritage for tourism, urban and memorial issues. However, the fragility and the dimension of the supports and the conditions required for their exposure makes this acquisition very difficult and expensive. Thus, the creation and the exploitation of a virtual model constitute an interesting alternative for these cities steeped in history. This creation of a digital model requires the availability of the town scale model as experiments led with Prague [1] and Toul [2]. In this article we present a new approach based on historical documentary resources represented by preparatory documents. These historical documents bring together all the topographic surveys made on the ground by the engineers of the time and were used as specification for the construction of the plans-reliefs. Some of this material has been digitized. The method of 3D semantic modelling of plan-relief presented here proposes to utilize these media as a data source for the reconstruction of a virtual historical city model similar to the original plan-relief which was built manually with this same data source. This paper presents the method exploiting preparatory documents made on the city of Verdun, which is currently enclosed in containers in Paris, to rebuild a virtual plan-relief Verdun. The preparatory documents and the modelling method are presented respectively in Part 2 and 3. Some valorisation applications of this virtual model are presented in the last part of the article.

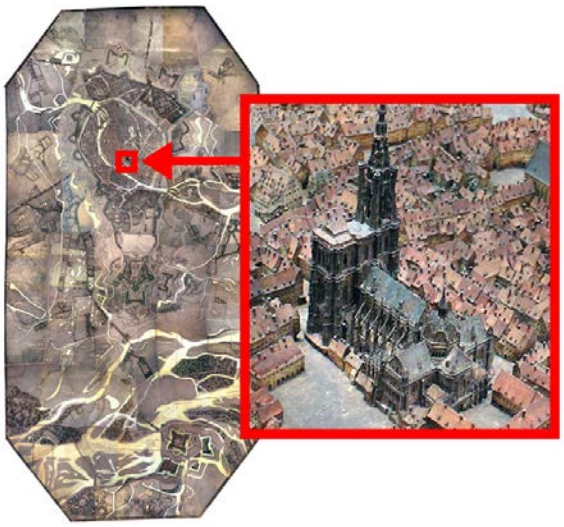

Fig. 1. Although the scale is 1:600, the objects shown on the model are highly detailed (for example, the 24 cm-high cathedral on the plan-relief of Strasbourg made in 1725-1758 and measuring 80 square meters (Musée historique de Strasbourg).

II. THE HISTORICAL DOCUMENTS

The plans-reliefs of the nineteenth century have been built according to several types of historical preparatory documents including many graphic documents. The *épures* are large plans depicting each parts of the scale model (*tables* in French). The drawing limits are irregular as they follow the delineation of

the parts of the scale models. Every constructed and landscape elements are drawn on these plans as well as contour lines [3].

Other graphic documents include the elevations and plans of each city block, hamlet, isolated farm or fortification work. These drawings were taken from field measurements that were conducted by topographer artists. The elevation views are in fact developed elevations (the sides of the construction are like unfolded nets), which may explained why these historical documents are called "book of nets" (*cahiers de développements* in French). The drawing scale is 1:600 like the scale-models. These graphic documents are also annotated giving precise knowledge of the nature of the materials used for walls, roofs, grounds, etc. For example, abbreviations are used to identify flat (f.t.) or barrel tiles (b.t.). Color and materials are specified for facades (warm shade, sepia, ochre, new, etc.).
The correspondence between plans and elevations is done through two types of annotations: letters to identify the courtyards and numbers to define portions of the elevations. The example illustrated in figures 2 and 3 shows a courtyard (Y) and elevations (1, 2, 3, 4, 1).

However, inconsistencies, errors and omissions are common and make it necessary to use *a priori* knowledge for addressing interpretation problems. Among the difficulties encountered, we noticed a lack of data. Spending more time to understand and to interpret documents can solve this problem. In addition, these graphics are not always readable and often present contradictions between them.

Another example of problem illustrated in figures 2 (inside the red area) and 3 (under the red arrow on the elevation), shows an inconsistency and parasite lines between the building (4 to 1) in ground plan and elevation. Note that on the plan (Fig. 2) between number 4 and 1 there is a single building, while on the elevation (Fig. 3) there are two buildings side by side. So, we see that the limits of the buildings are not readable and not well defined.

This ambiguity is the most common problem in some city blocks, with random segments and omissions that make it difficult to separate the boundary of the parcel and building type.

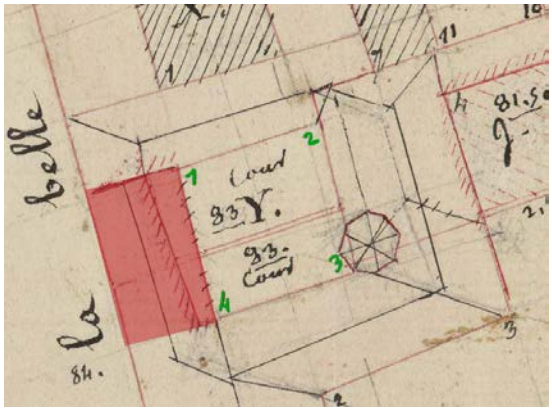

Fig. 2. Floor plan excerpt from a city blocks

Even if significant simplifications have been made in graphic documents, these materials offer a unique documentation on the evolution of cities, fortifications, architecture and countryside. That is why the museum of Plans-Reliefs started a digitizing campaign of its preparatory documents in 2010. Today, only two preparatory documents of six avalaible were digitized and made available on the web. Problems of access to the scale models have led the decision to use the orthographic projections contained in the preparatory documents to develop a new approach of 3D semantic modeling of plans-reliefs.

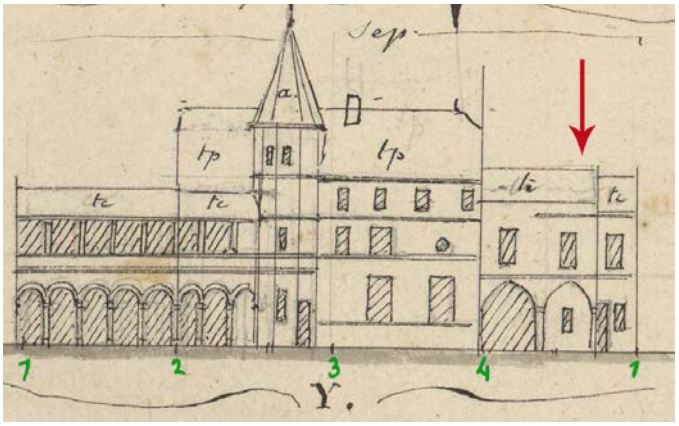

Fig. 3. Elevation overlooking the patio.

III. THE 3D SEMANCTIC MODELLING METHOD

Our modeling process is explained in Fig. 4. It is a knowledge-based approach that consists of two steps: the first one is common to all projects, whereas the second one is specific to each scale model.

Step 1: firstly, a knowledge model of the studied architectural elements (buildings and fortification works) is carried out (a) thanks to reference literature (e.g. classical and military treatises). Each kind of element is described in a library of parametric entities (b). This library can be enriched at anytime if required. For more details about the library, you can read [1] [4].

The second step is different depending on the studied elements; buildings or fortification works.

Step 2 for the buildings: secondly the modeling process consists of the following steps:

- semi-automatic step (d): 2D drawing of polygons in the plans : ground outline of the buildings and elevations. This step is manual for the ground plan (some tests carried out by specialists of this domain research did not produced exploitable results). For the elevations, simple algorithms allow us to automatically detect simple facades and their openings.
- Relations between the ground outline of buildings and their elevations are then manually specified. Each segment of the ground outline can be connected to a corresponding elevation (d).
- Finally, from a ground outline and its corresponding elevations, we automatically compute the 3D textured model of the building (e) according to a given parametric object of the library.

Step 2 for the fortification works: an automatic modeling approach (KASTOR) of the fortification works has already been developed for the post treatments of 3D survey data. The adaptation of this process with graphic documents as input data is still a work in progress: the main issue is to automatically extract the outline of fortification works (d) in order to use KASTOR for the 3D modeling (e).

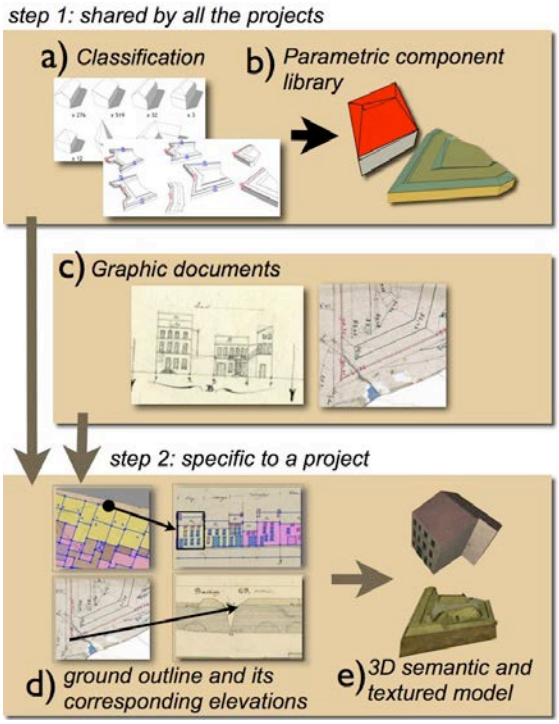

Fig. 4. Modelling process for the creation of the parametric elements.

IV. Valorisation Applications

3D models of plans-reliefs can be imported into 3D engine development platforms for creating applications in real-time 3D, such as Unity 3D, Unreal engine, etc (Fig.5). With some adjustments on 3D models when importing and writing a few scripts, it is possible to attach the knowledge related to the semantic modeling we made earlier. From there, the possible applications of valorization of plans-reliefs are many and varied.

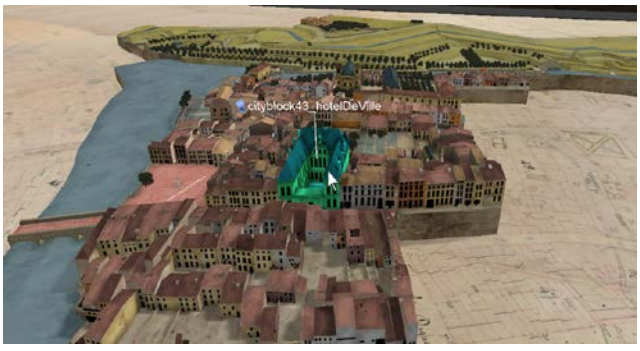

Fig. 5. 3D semantic model of Verdun plan-relief integrated in Unity 3D.

A. Kiosk

Conception of kiosks for visualization of plans-reliefs is possible. Interactive navigation can be done with a free hand gestural interface by using a tiny device called Leap Motion. Thus, through the airplane metaphor [5] allowing a fast and intuitive learning, everyone, even without browsing experience into 3D models, can easily navigate through the 3D model by flying over the plan-relief.

Figure 6 illustrates a free hand travel on a computer using Leap Motion device situated just below the hand.

Fig. 6. Free hand travel above the 3D plan-relief of the city of Verdun using the airplane metaphor.

B. Multi-touch and tangible table

The virtual model of plan-relief can also be used as interactive support on multi-touch tables. The semantic modeling of buildings allows an individual identification of each element. So, actions (such as displaying information, etc.) are possible when an interaction occurs (tap on an element).

Furthermore, multi-touch tables can manage a tangible interface by recognizing objects put on their surface, either by markers (as RFID, 2D pattern) [6], or by using sets of marks stuck under objects serving to simulate fingers [7]. Thus, the pose of an object on the table can launch actions: for example, the pose of a tangible model of church could highlight all the religious buildings (Fig. 7).

Fig. 7. Tangible table : the pose of a 3D printed object, that represents a church, highlights all the religious buildings in the virtual plan-relief

C. Tablet computer and augmented reality

The virtual model of plan-relief can also replace a town map on a tablet computer (Fig. 8). It is then used as support in mobile applications of educational rally in order to visualize the differences between the current city and what it was at the time period of the plan-relief. The virtual model and the knowledge attached to architectural elements can then be used and presented to the user as augmented information on reality.

Fig. 8. Tablet computer : visualisation of the virtual plan-relief of Verdun as a map used in mobile application of educational rally.

D. Augmented 3D printed model

A 3D printed model of the plan-relief can be make in white color with a 3D printer to obtain a physic object serving as screen for a video projector. Thus, the projection of a video on this 3D printed model is able to highlight various locations of the map in a synchronous way with an interactive application showing information attached to architectural elements.

Figure 9 shows a picture of an augmented 3D model. The differences of colors are due to the video-projector showing specific places according to user's interaction.

Fig. 9. Augmented 3D model of Barcelona *(Located at Col·legi Oficial d'Arquitectes de Catalunya. COAC. Plaça Nova, 5, Barcelona)*.

V. Conclusion

The creation and the exploitation of digital models of plans-reliefs constitutes for the represented cities a real opportunity for touristic, historical or urban valorization. The under development proposed method uses historical digitized documents. It allows overcoming the high cost and the difficulty of acquisition of a plan-relief and it is able to model most building types present in the different city blocks of the plan-relief of Verdun. More complex buildings like churches and administrative buildings are hand-modelized. The examples of valorization are under experimentation with the city of Verdun, financer of this project. A first studied improvement track concerns the modeling of more complex objects such as religious buildings where a parametric approach is being developed. Concerning the valorization applications, an exploitation of the 3D semantic model is envisaged in a GIS for the purpose of an urban scale usage by the general public or administrative services of the city. We also wish to replicate this experience using this method for modeling the plan-relief of Toul from its preparatory documents. We will then be able to compare this model to the one realized in a first project from a digital acquisition [2] and thus analyze and interpret differences and their origins (historical, technical, human).

Acknowledgment

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