Digital Applications in Archaeology and Cultural Heritage 1 (2014) 82–91

Contents lists available at ScienceDirect

Digital Applications in Archaeology and Cultural Heritage

journal homepage: www.elsevier.com/locate/daach

Automation in heritage – Parametric and associative design strategies to model inaccessible monuments: The case-study of eighteenth-century Lisbon Águas Livres Aqueduct

Helena Rua [a,*], Ana Gil [b,1]

[a] ICIST, DECivil, Instituto Superior Técnico, Universidade de Lisboa, Avenida Rovisco Pais, 1049-001 Lisbon, Portugal
[b] DECivil, Instituto Superior Técnico, Universidade de Lisboa, Avenida Rovisco Pais, 1049-001 Lisbon, Portugal

ARTICLE INFO

Article history:
Received 5 February 2013
Received in revised form
21 March 2014
Accepted 27 June 2014
Available online 8 July 2014

Keywords:
3D model
Parametric and associative geometry
Virtual heritage

ABSTRACT

This paper discusses a methodology used in the 3D virtual representation of monuments whose characteristics and function make them unsuitable for an integrated survey and modelling study. We therefore analysed the potential of Architecture, Engineering and Construction (AEC) tools, which combine geometry with alpha numeric metadata.

Parametric and associative geometry allows updating the automatic model so that whenever there is a new survey or new findings emerge, the whole model does not need to be reworked, except for the relevant components, which renders unnecessary its complete reformulation in future updates. This makes the modelling process applicable to any inaccessible monument. Moreover, it is also possible to explore the potential of these strategies for heritage management.

We chose an extensive monument, the Águas Livres Aqueduct, a Portuguese national monument in and near Lisbon, of which we present the first outputs in this paper.

1. Introduction

The purpose of this work was to devise a methodology that would enable modelling, using common tools and available data. The reason for not using sophisticated digital survey technology is mainly related to the fact that we want to implement a procedure affordable to any research work.

The study subject does to some extent reflect this lack of access to data because it is mostly buried. It would have to be excavated to conduct either a traditional or laser-scanner survey. This would be very hard to do in full, since the aqueduct is about 14 km long. However, the fact that we are using an existing building will ultimately make it possible to compare the model with the reality, and thus validate the series of procedures proposed, provided that prospecting and sounding work are carried out on the monument.

Since this model represents reality, i.e. with varying levels of detail depending on the data used, the following criteria were established for its implementation:

1- It should allow the upgrading of the information used in the model (geometric and relational) without having to redo the entire modelling process. This required the development of a parametric model.
2- It should be able to link technical information and historical references (alphanumeric) relating to the monument. This meant creating a BIM model.
3- It should be possible to use the model as the principal means of communication between the services responsible for its maintenance (technical and museological). This required establishing a relational database, to link the reports and photographs of the site visit.
4- It should be possible to use the model as a means of publicizing the monument through virtual tours. This meant developing a visualization model.

Basically, it is a way of making the sequence of modelling work more interactively by introducing cyclical processing, focused particularly on the data communication stages so as to extract new data that can be used in subsequent modelling stages (Fig. 1), since data acquisition is a consequence of an activity open to any user.

Abbreviations: AEC, Architecture, Engineering and Construction; BIM, Building Information Modelling; GIS, Geographic Information System; MDT, Model Data Terrain; GPS, Global Positioning System; EPAL, Empresa Portuguesa das Águas Livres (literally: Free-Water Portuguese Company, the body that manages the monument); IGeoE, Instituto Geográfico do Exército (Portuguese Army Geographical Institute)

* Corresponding author. Tel.: +351 21 841 97 64; fax: +351 21 841 23 44.
E-mail addresses: hrua@civil.ist.utl.pt (H. Rua), ana.cristina.c.gil@gmail.com (A. Gil).
[1] Tel.: +351 21 841 97 64; fax: +351 21 841 23 44.

http://dx.doi.org/10.1016/j.daach.2014.06.002
2212-0548/

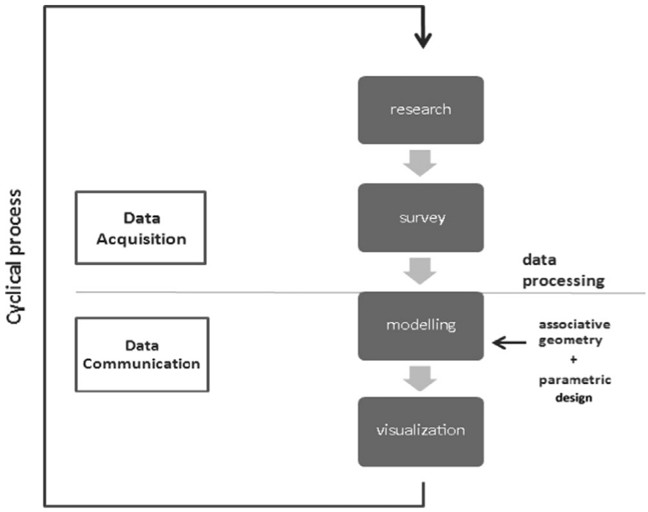

Fig. 1. Workflow of a modelling process, integrating associated geometry and parametric design.

In general terms, the main aims were

- to establish the procedures which assist in the use of graphic elements in historical/archaeological context;
- to build virtual models for heritage management purposes;
- to write an account of the historical facts so as to evaluate the topographic potential for piping water from Belas to Lisbon.

The specific goals were

- to identify the major limitations of current survey tools, especially when implemented on extensive monuments;
- to develop a database (standardized, as much as possible) related to the monument;
- to build a digital model that enables future updates, in particular georeferencing data components;
- to produce simplified sub-models that allow virtual tours;
- to propose a survey method and representation for this type of monument;
- to evaluate the automation of repetitive procedures (at least, in an initial phase) using programming language (such as Scheme), to minimize the introduction of human errors.

2. Related work

Register to preserve. While digital media cannot yet compete with the longevity of the analogue format (especially on paper), they are in themselves an excellent means for collecting, handling and subsequently disseminating data (Addison et al., 2006). Regarding procedures that have been providing and sustaining the survival of information on heritage, dissemination is more than a need; it is an obligation (London Charter, 2009).

The automation of data acquisition process has also helped develop models to represent reality. According to the technology used, these are efficient processes and widely applicable to determine the state of repair of built heritage.

The cultivation of survey techniques and equipment available for digital heritage, perhaps linked to the need to reconstruct the different stages of the life-cycle of a building, has gradually led to the creation of virtual heritage models which, by their nature, constitute either a centralized database on the property in question, or a medium for the visual communication of such data.

Models such as this are highly suitable for disseminating culture, not only for educational purposes but also to enable the general public to view and interact with heritage files and virtual museums. For instance, the *Rome Reborn* project, an international consortium which has created 3D digital models illustrating the urban context of ancient Rome (Guidi et al., 2005; Guidi et al., 2007; Frisher and Stinson, 2007; Dylla et al., 2009), accomplished two main purposes (Frisher, 2008): historical research (the restricted model) and public dissemination (the simplified model, generally accessible). It thus coincided with the UNESCO Charter for the Preservation of Digital Heritage (2003) early on, by promoting digital age heritage.

Using AEC techniques for virtual modelling is an area of archaeological research as yet little explored. We can mention the work of De Luca who has been using parametric programming languages to model the classical orders of architecture since 2003 (Dekeyser et al., 2003). Approaches of this type, establishing margins for varying parameters for each element – geometric atom or geometric primitive (De Luca et al., 2007) – are very relevant because it leads to the typological re-establishment of architecture. Bearing in mind that the introduction of universal standards of measurement was only introduced in the 19th century, this approach is extraordinarily well suited to draw inferences on the size of the module that is based on these proportions, as well as the geographical area of its influence.

More recently, authors such as Murphy et al. (2011) and Chevrier et al. (2009) offered their contribution to this field of research. Using models with BIM and GIS characteristics enables the creation of smart models, which assign properties related to three-dimensional georeferencing to the modelling components. As a result we can mention the creation of an extensive library of parametric objects essential for the generation and automatic update of large sections of a city.

In previous cases the parameterization was designed as a model for application to unknown cases, i.e. based on the classification of known elements, applying it to situations where there is uncertainty about the form and image of the building (creating catalogues), as happens for example with the architecture of mass-buildings of Roman and mediaeval cities.

The advantage of implementing BIM models in Heritage, namely the use of a tool mostly addressed to the architectural design in the reconstruction of historical buildings, is certainly related to the possibility of establishing a digital archive involving different types of information, graphical and alphanumeric, in the same database (Fai et al., 2011). Furthermore, the ability to model different scenarios for the same space, representing distinct epochs, allows establishing a sequence of temporal evolution of a particular site or cultural landscape. Architectural modelling tools also allow the addition of components based on the information of the construction process, which results in the creation of libraries of parametric objects. Implementing this process to model heritage buildings will enable sharing such data between the scientific community, besides implementing more efficient work process into new researches that will be developed in this field, and, in some way, to contribute to the *abacus* proposed by Oreni (2013).

The reason why this technology has not been widely applied to heritage documentation may be related to two technical aspects. The first concerns the way archaeological surveys have been recently made – as clouds of points – and the challenge to convert this data into a BIM system. Actually, and beyond the work of Garagnani and Manferdini (2013) which explores the fusion between these two concepts, based on a common software (©*Autodesk* Revit Architecture 2012), few studies encouraging the dissemination of these techniques are known. The second aspect relates to the limitations of BIM systems in reproducing the state of conservation and deformations that time causes in building