Digital Applications in Archaeology and Cultural Heritage 1 (2014) 92–102

Contents lists available at ScienceDirect

Digital Applications in Archaeology and Cultural Heritage

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

Reconstruction and generation of virtual heritage sites

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ARTICLE INFO

Article history:
Received 4 April 2013
Received in revised form
26 February 2014
Accepted 27 June 2014
Available online 5 July 2014

ABSTRACT

Traditionally procedural modelling techniques are commonly used to generate new structures and are presently established in several areas such as video games and computer animated movies. However they may also be used in heritage applications to efficiently produce models of non-existing worlds for which there is some kind of knowledge (e.g. floor plans, photographs) to support the reconstruction of realistic environments. Similarly they may also be used to support the generation of distinct possibilities that allow experts to draw some conclusions or conceive different hypotheses about lost worlds. The present paper shows the benefits and constraints that may arise from the use of such techniques in virtual heritage applications.

Furthermore, a whole method is proposed, for the reconstruction and generation of virtual heritage traversable house models, provided through the means of a grammar, demonstrated with the reconstruction and generation of several Roman houses from the heritage site of Conimbriga, Portugal.

1. Introduction

With the increasing demand for more complex and larger models in different fields, such as the design of virtual worlds, video games and computer animated movies the need to generate them automatically has become more necessary than ever. Manual tools are no longer sufficient to match this rising need and the impact that automatic tools may have within these fields is essential. Indeed, it is possible to eliminate most of the effort, associated with the creation of such environments, by providing tools that may generate “massive” 3D content automatically.

Still, there are also several other areas, such as archaeology, that may benefit from the use of procedural techniques and there are some related work addressing procedural heritage.

It is not the same to generate purely fictional structures and recreate existing structures. In order to assure the realism of the final models there is the need to account for many architectural concerns. Therefore, there are several aspects that have to be taken into consideration when dealing with the reconstruction and generation of virtual heritage worlds.

In this paper a method is presented which allows the specification of several features of a house, provided through textual specifications (using a grammar) allowing both the reconstruction and the generation of traversable houses. This feature is particularly useful, because it allows a user with no knowledge or experience with modelling tools, to construct his/her own models through a set of textual specifications.

Moreover the method also allows the use of incomplete specifications which allows the generation of several resembling models within an architectural style. The presented method is demonstrated with the generation of several Conimbriga's Roman houses (Conimbriga is a heritage roman site in Portugal) showing some dissimilarity amongst them.

The subsequent sections of this chapter start by presenting an overview of procedural modelling, and some projects concerning virtual heritage, as well as discussing several aspects concerning the use of procedural techniques in heritage applications.

Then, in the subsequent chapters, the several modules of the proposed method for the reconstruction and generation of heritage houses are described. After that, some results are presented and the major conclusions of this work enounced as well as some future work.

1.1. Related work

The introduction of this paper describes some features of procedural modelling techniques, showing their undeniable advantages in the generation of new worlds. Indeed, procedural modelling is the tool of choice, when addressing generation, but it may also prove to be useful to create virtual models representing

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http://dx.doi.org/10.1016/j.daach.2014.06.003
2212-0548/

structures lost in time, or even to create virtual models of existing structures (reconstruction). For these reasons it is important to first establish the significance of two different terms used throughout this paper: reconstruction and generation. The term "reconstruction" refers to the creation of models using automatic techniques representing existing structures or creation of models representing structures no longer existing but for each there is enough evidences (i.e. ruins, floor plans, photographs, etc.) to faithfully reconstruct them. The term "generation" refers to the generation of new worlds, i.e. automatic creation of fictional structures not intended to represent any ever-existing structure.

When considering urban procedural modelling, techniques have been applied in very different applications with different techniques and covering different aspects. They may centre the attention on the generation of individual houses (Martin, 2005; Rodrigues et al., 2008a, 2008b, 2009), on tall buildings and skyscrapers (Greuter et al., 2003; Parish and Müller, 2001; Park, 2005), or on large urban environments (Willmott et al., 2001; Lechner et al., 2003; Bostrom et al., 2004, applying urban planning principles to the design of virtual environments (Ingram et al., 1996), modelling from architectural rules (Fuchs, 2006; Luca et al., 2007; Rodrigues et al., 2008a, 2008b, 2008c), dealing with specific features as the generation of streets and roads (Parish and Müller, 2001; Chen et al., 2008), or on house specific house features such as windows (Charbonneau et al., 2006).

Likewise, they may focus on modern architecture (Bessa et al., 2005; Coelho et al., 2007; Martin, 2005; Rodrigues et al., 2008a, 2008b) or on heritage architecture, such as Roman (Müller et al., 2005; Rodrigues et al., 2007, 2008c) or Mayan architecture (Müller et al., 2006a). Indeed, procedural techniques have been used to create heritage models representing ancient structures. For example, in Müller et al. (2005), the authors wrote a set of rules to generate a virtual model of Pompei using CityEngine, a system introduced by Parish and Müller (2001). Later, using the same system, the authors of "Procedural 3D Reconstruction of Puuc Buildings in Xkipche" (Müller et al., 2006a) generated Puuc-style buildings, similar to the ones that may be found in the ancient Mayan site of Xkipché, in Mexico. This system was also used with other examples shown in Müller et al. (2006b).

In structures showing more complex geometries, the aforementioned techniques (i.e. the definition of sets of rules to describe the physical geometry of physical structures) may prove to be, in several cases, harder to achieve (or take more time) than when using traditional methods (manual modelling) or even be impossible to realise. Indeed, an experienced modeller may produce 3D models very efficiently when given adequate data (e.g. measurements, photographs, etc.) about a physical structure. Unfortunately, manual modelling does not allow the efficient reproduction of large virtual environments showing diversity (e.g. creation of different houses corresponding to a similar architectural style).

Other projects, such as "Rome Reborn" (Frischer et al., 2008), use both reconstruction, which currently is done manually, and generation. One of the goals of this project was "to create a 3D digital representation illustrating the development of the city of Rome in antiquity from the first settlement in the late bronze age to the depopulation of the ancient city in the 6th century AD". Hence some of the buildings present in the digital model are manually modelled, based on archaeological evidence (such as excavations, studies and ancient literary sources). Other buildings are procedurally modelled from a digitisation of the Plastico di Roma Antica, "a large plaster-of-Paris model of imperial Rome (16×17 m^2) created in the last century" (Guidi et al., 2005a, 2005b, 2008; Kimberly et al., 2009), by replacing the scan data from the digitisation with geometrically simplified forms, and the modelling of these simplified form faces with detailed architectural features (e.g. doors, windows, balconies). Another interesting feature about "Rome Reborn" is that the aforementioned CityEngine, the urban modelling software from Procedural Inc., was used in the procedural modelled buildings (Kimberly et al., 2009).

1.2. Procedural heritage

When addressing reconstruction or even considering a procedural technique for reconstruction it is important to think in which areas it may be applied. So, one may think at most obvious areas such as archaeology, architecture, etc. This raises some questions concerning the ability to represent or reconstruct structures using procedural methods since, for example, in areas such as archaeology one main key point to recreate the past is the realism, which means that it is crucial to create features with a higher level of detail. Therefore, in some situations, it is advisable to use manually modelled objects rather than to try to use some algorithm which would resemble the real structures that are pretended to be represented. Producing these realistic models may be achieved either by designing them from known similar objects (e.g. artefacts, columns, windows, etc.) or even by replicating existing ones. Independently of how the models are created, the fact is that often there is evidence which indicate that most probably, within a certain architectural style, similar structures have identical features.

Considering the aforementioned constraints it is important to reason how procedural modelling techniques may be useful when dealing with areas such as archaeology. One way is to efficiently produce models of non-existing worlds for which there is some kind of knowledge (e.g. floor plans, photographs) to support the reconstruction of realistic environments. Other is to support the generation of distinct possibilities to allow experts to draw some conclusions or conceive different hypotheses about lost worlds. For example in several Roman heritage sites (e.g. Conimbriga, Portugal) some parts of the city are yet uncovered or may even be lost. By taking as an example similar Roman cities it is possible to determine what may exist in most of the site and, this way, produce new models resembling existing structures.

The idea of generating structures similar to existing ones is not something new and not even confined to heritage. In fact, it is something that is pursued by several authors and may be referred as inverse procedural modelling. For example, in Aliaga et al. (2007), the authors describe an interactive system for the creation of new buildings in the style of others or for the modification of existing buildings. The idea is to create geometric models from photographs, divide the building into their basic external features (e.g. floors, windows, etc.) and create a grammar that captures the repetition patterns of these features. Then it allows the user to design building configurations from building blocks and finally to divide these building configurations into the several features, using the repetition patterns from the grammar. One of the most interesting aspects of this approach is the idea itself and its potential use in architecture. Nevertheless, there is still a great deal of interaction needed from the user, starting from the initial photograph mapping until the design of the final building blocks (the interaction in this last step does make a lot of sense if the idea is for the user to control new geometries). Another aspect to notice about this approach is that only facades are created.

The next chapter describes a method which uses procedural modelling techniques and yet maintains the realism of the virtual models, by using a hybrid approach.

2. Method architecture

Within this chapter the main features of the method for the reconstruction and generation of architectural-period traversable