Procedural modeling historical buildings for serious games

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Resumen

En este trabajo apuntamos al objetivo de obtener edificios históricos virtuales con alto nivel de detalle, como por ejemplo un castillo o un barrio de una ciudad antigua, a través de una metodología que facilite su reconstrucción. Las herramientas que proponemos nos permiten obtener rápidamente un modelo aproximado y flexible para ser explorado, analizado o eventualmente modificado. Modelos con estas características son esenciales para el desarrollo en plataformas de juegos serios, cuyo objetivo fundamental se centra no sólo en la precisión y el realismo, sino también en transmitir una sensación de inmersión para el jugador.

Palabras Clave: *MODELADO PROCEDURAL, ARQUITECTURA HISTÓRICA.*

Abstract

In this paper we target the goal of obtaining detailed historical virtual buildings, like a castle or a city old town, through a methodology that facilitates their reconstruction. We allow having in a short time an approximation model that is flexible for being explored, analyzed and eventually modified. This is crucial for serious game development pipelines, whose objective is focused not only on accuracy and realism, but also on transmitting a sense of immersion to the player.

Key words: *PROCEDURAL MODELING, HISTORICAL ARCHITECTURE.*

1 INTRODUCTION

Virtual 3D city models with detailed geometry, including historical buildings, are required as contents in visual applications involving education or cultural heritage preservation, and they take an even more important role in serious games with an historical setting. Obtaining such kind of models is a hard task. The main reason is that data acquisition is not always possible, and in some cases such data simply is even nonexistent. In addition, city models are often huge, and manually modeling them is a tedious and complicated task. This task might involve hundreds or even thousands of man-hours to develop a full city, as each model might need many details to be realistic.

In this paper we propose a methodology that facilitates the reconstruction of historical buildings, like a castle or a city old town. The methodology goal is to allow designers or game creators to build, in a short time, a high quality approximation of the model being explored. In this way, not only the labor-intensive manual-modeling task is avoided, but also a flexible way to analyze, change and tune the model is provided.

Our approach it is based on procedural modeling [1], which has proven to be quite effective for urban environment creation [2]. This methodology offers a potential alternative to the labor-intensive modeling tasks required by traditional 3D modeling techniques for building reconstruction. We provide a set of

tools to help and automate, as much as possible, the generation of the reconstructed model. Starting from available cartographic information, we address all steps in the pipeline, from the generation to the management of geometric detail. The objective is to produce geometry feasible for using in game development platforms. In particular, we believe that our approach is feasible for application involving serious games, where a historical or educational goal is the main objective of the game. Several different and complementary phases involve the creation of such kind of games. The main contribution of our work is to provide automation tools for 3D content generating, freeing creators to focus on scripting tasks with a wide range of possibilities for model inclusion. In Section 2 and 3 we review the main topics related to our work, the reconstruction of historical buildings and procedural modeling, respectively. Our reconstruction tools are presented in Section 4 and example tests are presented in Section 5.

2 THE RECONSTRUCTION PROBLEM

Virtual 3D models of buildings and sites that have changed, have suffered massive damage or even have disappeared completely, can serve many purposes. First of all, they can be used as object of study to investigate the features of a currently inaccessible site. In addition, they can contribute enormously to the dissemination in presentations for public communication, mainly for promotion of cultural heritage assets. Also, integrating them in modern digital metaphors, like computer games, can potentially increase the impact of communication with educational purposes. Current gaming technology can provide an immense sense of immersion to the player, which can be used to convey an educational, and not only entertaining, message. However, providing accurate model reconstruction is a challenge since available data is limited and sometimes, even non-existing. Many works have been proposed to solve related aspect, like recreating the city structure [5], or generation of building envelopes, or facade composition [3]. A complete state of the art overview that contains the most relevant literature of all these topics can be found in the work by Musialski et al. [2].

It is important to consider that the limitation of data quantity and quality often also leads to a large source of uncertainty. Haegler and coauthors [3], explored procedural modeling to keep uncertainty as a source of realistic reconstruction. The way this uncertainty was modeled in their system was through probabilistic rules. This strategy also yields flexibility to play with changes as an archaeological research tool.

3 PROCEDURAL MODELING

The seminal work by Müller et al. [1] introduced Grammar-based procedural modeling for building. The main concept of this technique is a shape grammar, which is based on a rule-base: starting from an initial axiom shape (e.g. a building outline), rules are iteratively applied, replacing shapes with other shapes. A rule has a labeled shape on the left hand side, called predecessor, and one or multiple shapes and commands on the right hand side, called successor:

$$PredecessorShape \rightarrow Successor$$

The main commands, the macros that create new shapes in the classic approach are: *Subdivision* that performs a subdivision of the current shape into multiple shapes, *Repeat* that performs a repeated subdivision of one shape multiple times, Component split that creates new components shapes (faces or edges) from initial volumes, and the *Insert* command that replaces a pre-made asset on a current predecessor. The whole production process can be seen as a graph where each node represents an operation applied to its incoming geometry stream and the leaf nodes are the geometry assets (see Figure 1).
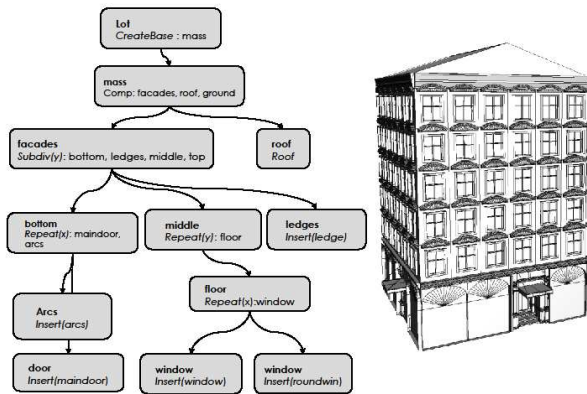
Figure 1: An example of a building generated with procedural model. From the mass envelope, a generic subdivision scheme is encoded through rules and labels to describe completely the building with details.

4 PROCEDURAL TOOLS FOR RECONSTRUCTION

Our methodology encompasses a set of tools that provide a large degree of flexibility for reconstruction of historical buildings. In this section we describe these instruments addressing some fundamental aspects of the generation: mass-model generation, structure positioning, façade generation and geometry details management. An overview of the whole system and its internal implementation can be found elsewhere [4].

2D-Data and Block generation

The first step to generate an accurate reproduction of a historical building is the reproduction of its base plan. For that reason, we provide the integration of 2D-GIS data, such as floor plans or height maps, for the 3D reconstruction. Obtaining 3D mass-models by extrusion is a classic operation. However, there are many situations where the piece of provided data may have inconsistencies and errors, being much unreliable for 3D reconstruction. To solve this problem and enabling the use of such corrupted data, we integrate a cleaning and structuring algorithm, which guarantees that the 2D data is ready for reliable 3D extrusion [10].

Another inconsistency frequently found in historical maps is that are distorted. This distortion can be measured relative to current, more accurate maps. In this case, if we want to integrate historical buildings at current urban scale, a calibrating processing is required. In our system a manual correspondence is supervised by visual inspection. A more advanced approach is to automate this process by bi-linear interpolation, as presented in [5].

In our methodology, 2D maps are also used for specific element structures that are not generated by extrusion, but by instantiation. This is the case, for example, of columns or decoration statues. In this case we provide methods to easily encode and design in a user-friendly way the rules needed for procedural positioning such structures. Figure 2 shows an example of an historic map of Carcassonne's medieval town, where some structures, as the towers and the wall, must be reconstructed. Our high level tools allow the user to provide a simple curve and a few constructive parameters, and the system automatically provides the positioning for these characteristic elements. This way, even non-expert users can quickly and effectively include walls, towers and gates to a castle or walled city.
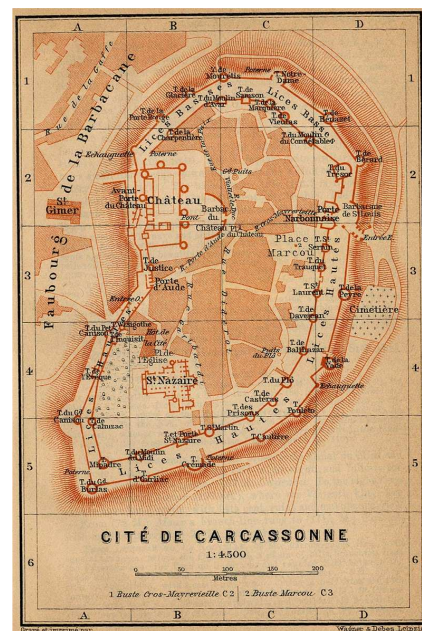

Figure 2: Historic map of the walled old town of Carcassonne, France.

Building Detailed Facades

Generating realistic facades from acquired data, as photographs or documented drawings, could be a laborious task if done with traditional 3D modeling tools. One way to automate the generation process is by integrating computer vision techniques with procedural modeling [2]. However, these techniques are preconditioned to a high quality acquisition, which is not always completely available in the case for historical building.

Instead of using an automatic façade detection approach, we provide modeling building facades tools, both for geometric details or for textures, using rule-based grammar, but through a visual programming language [6] (see Figure 3).
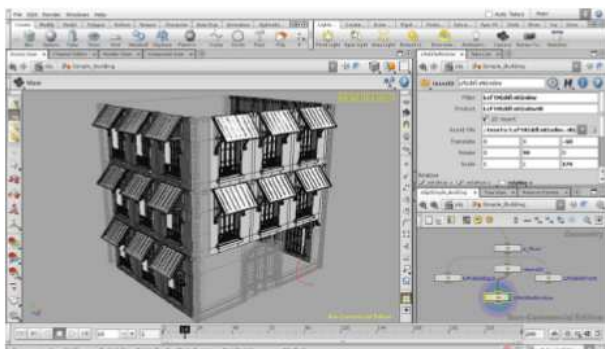

Figure 3: An example of visual interface for programming rules of a building interactively

Our proposal is that the user, through a visual interface, constructs and modifies the building by creating components that are interconnected on the screen. This result in a streaming visual node editing paradigm for shape grammars, where each node would be an operation applied on its incoming stream of geometry. This visual improvement would give a more intuitive interface than the classical text-based approach.

The natural way to encode a building façade in most modern buildings using grammars is by using the generic subdivision scheme. That is, beginning from the mass-model, sequentially splitting the façade into floors, and then into windows (see Figure 1). The terminal rules are managed by the *Insert* command, which is responsible for including detailed pre-defined geometric shapes. These usually are the typical shapes used for the target architectural style which is being modeled (for example a Gothic window or a Greek capital). In our system, the user can select the shapes form any predefined library, and easily preview the overall impact of that change on the final model.

We also provide commands for managing uncertainty using probabilistic and conditional rules. This is an important issue in historical buildings where the reconstruction of a building is performed in the presence of uncertainty. Probabilities can be associated to the rules according to the inferred frequency that a given structure has. Conditional rules can be associated to the successors of a rule where the result of evaluating a condition may produce different products.

On the other hand, when there are no records of the original building structure, the best an expert can do is an educated guess of its original structure and appearance. We propose an extrapolation methodological step that allows the user to reuse parts of the ruleset of known buildings to test for the new one. This extrapolation is usually based on a known building with similar structure, which can be reused in order to increase the fidelity of the reconstruction. We call this *extrapolated* reconstruction.

Managing geometric details

Besides the reconstruction problem, creating a urban landscape for a serious game also faces another problem: managing geometric complexity. It is a well-known fact that procedural techniques have the ability of producing large amount of geometry from a small input (the rulesets). However, this feature can result in a geometric explosion that must be controlled for a game engine to handle all the geometric detail a procedural modeler can produce [7]. Without any control, it can generate a large quantity of geometric data that may be excessive for efficient interactive visualization,

as required in games. Thus, we provide a set of tools for controlling the amount of generated geometry. In [8], level of detail is implemented by programming different rules for each geometry level.

With the aim of giving the user the possibility to set and select specific interesting shapes that may be important, and where a more detailed representation in the reconstruction would be required, we developed a more flexible and automatic method for achieving different levels of detail according to the user needs. For example, the user may decide to focus on the main door and towers of a castle, preserving the details for these structures and simplifying to texture the rest of the model. The algorithm works on the base of a graph transformation of the model representation derived form a semantic description of the structures to be kept [9].

5 EXAMPLES AND DISCUSSION

In this section we show reconstruction examples applying the tools presented. As a first example, we applied our system to the reconstruction of Carcassone walled city (see Figure 2). A first prototype can be seen at Figure 4.
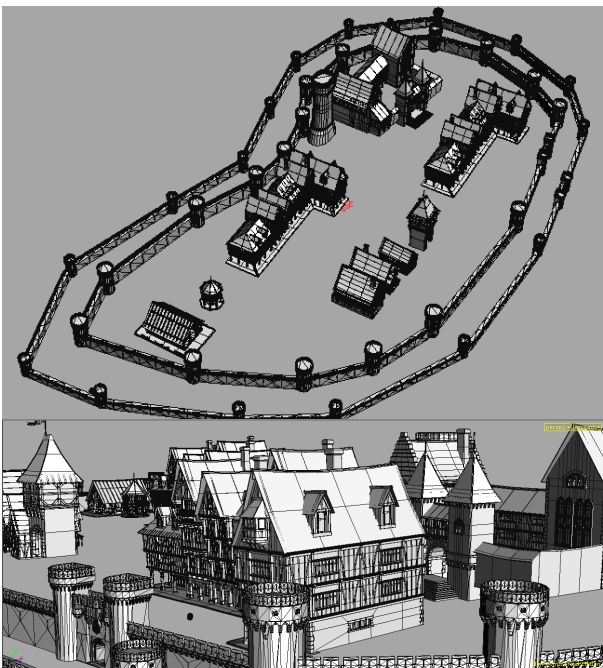

Figure 4: Two views of our prototypical reconstruction of the walled city of Carcassone's old town.

The creation of complex buildings is also possible, at the price of requiring detailed constructive information to obtain an accurate reconstruction. For ancient buildings that are still present, this reconstruction can be done using simple photographs. For instance, in Figure 5 we can see a few photographs taken for the reconstruction of the Raccolet House, a medieval house in Moret sur Loing, a town approximately 50 km south-east of Paris, France.

Figure 5: Actual photographs from the Raccolet House, Moret sur Loing, France, used as the starting point for our procedural reconstruction.

Figure 6: Procedural reconstruction of the Raccolet House.

Starting form these photographs, an artist recreated a first version of the house, which was used for the generation of the procedural rules for the final recreation. This recreation can be seen in Figure 6. In this example the reconstruction has been very detailed, as sufficient information is available to deal with the extra complexity. However, this is not always the case.

Having accurate reference models may provide an invaluable help when reconstructing buildings from which there is partial or missing data. In this case, an accurate reconstruction can be fairly difficult if not completely impossible. For that reason, the designer of an urban landscape of a historic city has to rely, quite often, on partial data, and extrapolate the missing parts. For instance, a complete reconstruction of the medieval town of Moret sur Loing is impossible, as several buildings have been destroyed or re-built in modern styles. For that reason, we propose to *reuse* assets from a known example (e.g. the Raccolet House) to *extrapolate* the many unknowns that might appear in a whole neighborhood reconstruction. See Figure 7.

Figure 7: A medieval neighborhood built from the assets from the Raccolet House (colored in front) with the technique of extrapolated reconstruction.

In order to control the potential geometric explosion that procedural modeling techniques may introduce, we have developed a customizable level-of-detail technique that allows the user to select the important features to preserve and which ones to simplify. Examples of these selective simplifications can be seen at Figure 8, where the lower floors or the upper ones of the Raccolet House were selected for simplification.
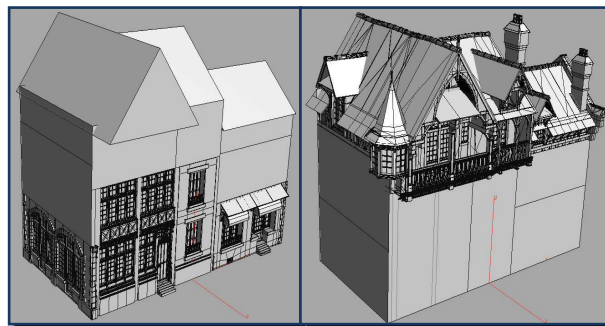

Figure 8: Selective simplification for level-of-detail management, applied to the Raccolet House.

A more sophisticated example of these techniques was used to perform a reconstruction of the city of Nantes (France), visualized in wireframe in an interactive environment in Figure 9. In this case a generic rule was applied to all buildings in one street of the city center.

Figure 9: Nantes city center reconstruction, one street has been selected for representation with geometry details.

A final comprehensive example can be seen in Figure 10, where it can be seen a schematic reconstruction of the city of Girona, with an enhanced model of the Romanesque Cathedral (figure center) and the Sant Feliu church (figure left). These two ecclesiastic building where built with the techniques described elsewhere [11].

Figure 10: Girona's reconstruction.

Discussion

We have presented a reconstruction methodology composed of a few easy to integrate steps. All together, this new methodology enables the recreation of historic cities and buildings. The resulting reconstruction can be used in any academic or commercial setting, but for the particular context of serious games we also provide complexity-management tools that greatly facilitate geometry integration in current production pipelines. Also, it compares better to traditional modeling. We have presented several case studies that show that the system is able to reconstruct different classes of buildings, resulting in an outstanding tool to complement standard platforms as CityEngine.

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