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Telmo Adão
Luís Magalhães
Emanuel Peres

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Telmo Adão · Luís Magalhães
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Telmo Adão
Department of Engineering
University of Trás-os-Montes e Alto Douro (UTAD)
Vila Real
Portugal

Luís Magalhães
Department of Information Systems
ALGORITMI Center, University of Minho (UM)
Guimarães
Portugal

Emanuel Peres
Department of Engineering
INESC TEC (formerly INESC Porto) and University of Trás-os-Montes e Alto Douro (UTAD)
Vila Real
Portugal

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Contents

Chapter 1
Introduction

Abstract Most of the existing procedural modelling solutions still lacks from support to the generation of virtual buildings with both exteriors and interiors composed by arbitrary shapes. To address this issue, a new procedural modelling methodology is presented in this book, one that produces virtual models of buildings, including exteriors outlined by arbitrary shapes and interiors formed by convex polygons. Regarding this specific chapter, some relevant subjects that define the boundaries of this book are introduced along with the motivation and goals that lie at the basis of the new methodology. Afterwards, a list of main contributions and assumptions are presented, shortly before book organization section.

3D virtual models of buildings are commonly used in areas such as architecture and video games to preview a house project and to populate a virtual scenario, respectively. Traditionally, the production of these models requires highly skilled manpower and a considerable amount of time. To address this issue, many researchers have developed semi-automatic techniques to produce virtual models expeditiously. These procedural techniques provide different ways of generating buildings, including interiors and outer facades, to serve several purposes (e.g., content generation for video games or archaeological reconstruction). However, the existing techniques focusing on building interiors usually only support the generation of floor plans constrained by regular shapes or contour polygons obtained from rectangles sets. At the same time, the possibility of modelling interior rooms through the specification of its constraint walls remains poorly explored. Moreover, most of the existing procedural generation solutions are guided by complex grammars concerned with geometrical aspects or semantic structures that fit specific project requirements, apparently disregarding the established standards for virtual urban environments, specifically, CityGML.

To overcome the noted issues, a novel procedural modelling methodology is presented in this book, one that produces virtual models of buildings, including exteriors outlined by arbitrary shapes and interiors formed by convex polygons. Methodology's regulation is provided by a building ontology—a CityGML-based knowledge structure [1, 2], planned to be extensible to specific architecture styles—through several guiding data structures such as structured XML and ontology-based

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grammar. Regarding the supporting process, a treemap approach is used to subdivide the building layout into floor plan areas. Several improvements were progressively made to the treemap in order to enable the subdivision of different constraint polygon types which range from rectangles to arbitrary shapes. Moreover, in the most advanced methodology stage, a method concerning inner room walls adaptation is addressed. Next, a set of operations is performed, from the marking transitions step to the extrusion process that provides the 3D aspect. In addition, an experimental stochastic approach is shown to automate the production of random buildings using this procedural modelling methodology.

Nearby the end of the book, a set of tests to evaluate the capabilities of the referred methodology in producing buildings characterized by arbitrary shapes and distinct architectonic requirements will be presented. Furthermore, the results of the performance tests will be shown.

Regarding this specific chapter, a few subjects will be introduced, concretely the production of contents for virtual environments, procedural modelling and also ontologies. Those subjects constitute the boundaries of this book which has its motivation and goals presented shortly afterwards along with some assumptions. This chapter ends with the main contributions and orientations regarding document organization.

1.1 Content Production for Virtual Environments

Content production for virtual environments is an important subject as it is directly related with parameters such as production cost and development time, which have a significant impact in how well a business or research performs. The conventional production of these models—specifically, using manual modelling—requires highly skilled manpower and a considerable amount of time to achieve the desired virtual contents, in a process composed by many stages that are typically repeated over time.

As technology continues to evolve at a faster rate—more processing power, faster and larger memory, increased disk space at better r/w rates and more powerful graphic boards—new paradigms are emerging to provide more efficient and cost-effective solutions for business that depend on virtual contents. Among them is procedural modelling which can be seen as an assortment of techniques that aim to automatize the production of virtual models through the assimilation of patterns and algorithmic approaches that assume the role of content production engines. From the perspective of some business and research areas (e.g. architecture, archaeology, videogames producers), the overwhelming use of resources can now be drastically reduced, leading to the increase of competitiveness. Moreover, man-skilled labour can now be concentrated in the validation and improvement of the automatically produced models by adding or altering particularities and details that might make them closer to the expected results, considering the requirements of a given modelling task in a certain context.

The application fields are numerous. Videogames industry is perhaps one of the most obvious cases, due to the use of complex road networks and rich urban environments, pretty noticeable in games, such as Grand Theft Auto (GTA)[1] or Need For Speed (NFS).[2] Actually, NFS was a case study for Watson et al. [3] who had underlined the applicability and importance of procedural modelling in the production of certain game contents, such as buildings and road networks, due to its cost-effective and dynamic nature. Moreover, they suggest that designers who demand for automatic ways of generating game contents to avoid tedious and repetitive hand-made tasks, can be supported by procedural modelling tools to generate the first set of urban objects, that afterwards can be customized to make them look like what they have projected.

The same modelling style can be used in the archaeological research area, even in damaged structures—as it is pointed out by Müller et al. [4], Rodrigues et al. [5] or Dylla et al. [6]—to aid, for example, in the proposal of hypothesis that can be valuable for the formulation of theories among that scientific community.

Another application field is 3D cinema. Enterprises like Pixar[3] or Dreamworks Animation[4] are specialized in producing 3D movies that include human and animal characters, cities, villages and forests. Some of their productions already take advantage from procedural modelling techniques. For example, in the Monters Inc. (Pixar) movie, the hair of Sulley character is procedurally animated [7]. Another example is the fracturing and debris procedural technique that was developed for Kung-Fu Panda (Dreamworks) in order to be applied in several scenes involving massive destruction of structures [8].

These were just a few examples intending to show procedural modelling versatility. However, others will be provided in the next chapters, to demonstrate the wide range of applicability of this modelling style in the generation of structures—specifically, buildings—expeditiously and demanding low user interaction.

1.2 Main Concepts

The concepts inherent to the areas addressed in this book will be presented, namely, ontologies and procedural modelling. Building Information Modelling (BIM) disambiguation closes the section.

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[1] Grand Theft Auto, also known as GTA, is a well-known role playing game series, developed by Rockstar. For more information, check the link: http://www.rockstargames.com/grandtheftauto/.

[2] Need For Speed or NFS, is a racing game series developed by Electronic Arts. For more information, check the link: http://www.needforspeed.com/.

[3] Pixar is a digital animation enterprise that belongs to the Walt Disney Company. For more information, check the link: http://www.pixar.com/.

[4] Dreamworks Animation is a north-american studio specialized in animation movies. For more information, check the link: http://www.dreamworksanimation.com/.

1.2.1 Production of Buildings Using Procedural Modelling

The production of buildings and urban environments are major concerns for the procedural modelling area. Many works [6, 9–11] present different approaches for the procedural generation of extensive urban environments, considering the exterior facades. These solutions have demonstrated to be a reliable alternative to manual approaches, since they are also capable of producing representations endowed with high levels of detail and visual accuracy. Regarding time consumption, the procedural solutions are incomparably faster. The same conclusions are valid for the generation of buildings considering their interiors [5, 12–14] which proposes the fully production of such structures including exterior facades, inner rooms and also the transitions that ensure transitivity among them.

1.2.2 Regulation Through Ontologies

Ontologies are knowledge structures capable of describing a system, namely the relations between its parts. They have been successfully applied in different solutions that require the use of virtual models/environments [15–17] to achieve a wide variety of purposes that range from the planning of neurosurgery operation to the cataloguing of museum artefacts. A few procedural modelling solutions also used them to guide the process of generating virtual models [13, 18, 19]. The results are interesting. However, most of these procedural modelling solutions seem confined to the context for which they were developed, disregarding standards oriented for virtual environments.

1.2.3 Ontology-Based Procedural Modelling Versus Building Information Modelling

This subsection intends to clarify the main differences between ontology-based procedural modelling approach and Building Information Modelling (BIM) which, due to the common use of semantics and similar goals, are liable to cause confusion.

BIM supports the development and use of a computer-generated model to simulate the different stages of a facility such as planning design and construction. Its preciseness, flexibility and huge range of possibilities make it suitable for construction professionals [20]. It is a complex standard that mixes semantic and geometry and contains a complete set of information—including, for example, the air conditioning system, the building structure or even the materials of its walls—and which requires expertise and labour when dealing with it, in order to meet client requirements and also legal and physical rules.

On the other hand, ontology-based procedural modelling is concerned with the rapidly and faithful visualization of virtual structures, disregarding imperceptible