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Proposal of an Information System for a Semi-automatic Virtual Reconstruction of Archeological Sites

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Abstract

In some business areas there is the need to use representations of places or buildings in order to provide visual informations. These representations are, mainly, reconstructions of scaled real models or virtual representations produced in a Computer-Aided Design (CAD) tool. Recently, procedural modeling has been applied to generate buildings and cities in a short time and with a minimum user intervention. This methodology reveals to be a promising solution for a cost-effective alternative in models construction. One of the areas that can benefit from this kind of approach is archeology, for example to test archeological hypothesis. However, the existing solutions are not flexible enough to provide high detailed models containing building interiors and exteriors. This paper aims to present the global architecture and specification of an information system that supports the procedural modeling process, producing enhanced virtual representations of ancient places, including building facades and interiors, using the information available.

Keywords: procedural modeling system; procedural modeling architecture; 3d reconstructions; virtual representations; computer-aided engineering; computer-aided design (CAD).

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1. Introduction

The use of virtual representations is useful to provide knowledge about a place or a building. Business areas such as tourism, urban planning, architecture and archeology employ different forms of virtual representations in order to achieve the respective purpose, for example to show a holiday destination, manage urbanization, present a house planning or study some ancient aspect in a cultural heritage site. Usually, build such representations is expensive and time consuming, since it uses several equipments, materials, software licenses, and can be a labor intensive process. In the archeology area these can be amplified by the necessity of test different archeological hypothesis, which may imply the construction of several virtual models. Besides, in the archeological area, the production of models demands consulting of information from geospatial data gathered from a given site and textual descriptions provided by different sources. The latter are usually non-structured information sources that need to be processed and mapped to a structured format. These sources are very important as information providers but cannot provide direct visualization. Instead of that, an arduous analysis is required to build the models through the expensive mentioned techniques. However, this painful process can be automated and models can be built expeditiously. It is in this part that procedural modeling reveals itself a powerful process to avoid time and labor consuming on models production.

Procedural Modeling is a method that employs several techniques to generate virtual models expeditiously, based on a set of rules. Many researchers have proposed approaches to generate 3D models of buildings and entire cities using this method. However, building's generation is mostly done focusing the production of outer facades rather than building interiors. In this paper it is presented a specification of an information system that supports the generation of building interiors and building exteriors according to heritage architectural rules and based on a set of information sources.

The information can be available in a structured or non-structured format. The processing of the information presented in non-structured information sources (such as documents and ancient books) involves an extensive analysis and is labor and time consuming. Even in the cases where the information is available in a structured format, there is the need to process the information in order to map it to an unified model. Therefore, it is proposed the integration of a module capable of automatically extract and convert information found on textual descriptions into a structured format and map all the information, even the ones that come from a structured information source, to an unified model.

In this paper, it is presented the ERAS information system, an expeditious modeling tool proposal for the reconstruction of archeological sites, endowed of the necessary flexibility to provide traversable buildings of several different architectonic styles. Firstly, the general architecture will be discussed. Next, the information system specification is presented. The functional requirements of this information system will be also exposed. Then, the 3D model generation process is detailed. The information system specification ends with the description of its static structure. This specification will be used to guide the development of a tool to reconstruct and visualize archeological sites with complete buildings (interiors and exteriors) considering the parametric values that are conformed to the rules defined for the period of time as settled, and architectural issues.

2. Background

Most of the existing systems to expeditiously generate buildings concentrate their efforts on the generation of modern structures. In the past years, several authors (e.g. [1-8]) presented different approaches to address different issues related with Procedural Urban Modeling. Watson and co-workers [9] discussed several other aspects, advantages and practical applications, from where generation of ancient cities can be detached. The authors cited two examples in which procedural modeling was applied to generate historical cities: Roman Pompeii [5] and Mayan Xkipché [10]. The focus of the generation of these works is on building exteriors. In most of the approaches, the generation of structures interiors is not a concern, thereby they are not traversable. Hahn et al. [11] presented a system to generate interiors in real time. The authors divide a rectangular floor randomly into rectangular rooms and hallways. In [4], the author present a graph based solution to generate the house divisions. The graph nodes represent the house divisions and the edges represent the connection between them. After graph generation, the rooms were placed in space and expanded with a Monte Carlo algorithm. These two methods proved to be insufficient when the goal is the representation of real buildings. In Rodrigues et al. [12], the authors proposed a solution to generate traversable modern houses using a L-System to generate the interior rooms and considering architectural legal rules. In [13], the authors extended the previous method to generate Roman civilization structures in a process guided by rules based on Vitruvius literature, mostly through the reading of the Portuguese adaptation “Tratado de Arquitectura” [14].

According to Watson and co-workers [9], one of the most challenging aspects to develop a system for procedural modeling is the automated production of rules. Muller et al. [15] developed a system to deal with this goal in where they created algorithms to automatically detail single facades by derivation of shape grammars. On the other hand, the automatic generation of rules based on textual description, requires computerized interpretation and extraction of relevant information.

In [16], the authors attempted to generate building models from textual descriptions in Portuguese language. To achieve this, a Portuguese version of Nooj [17] was used, the Port4Nooj [18]. This tool enabled the extraction of the relevant informations from a document description. These informations were used by the authors’ algorithm to build a cityGML [19] representation of a simple 3D church’s model.

3. ERAS General Architecture

The development of an information system capable of generate 3D models expeditiously addresses two main purposes: to reduce the amount of human intervention and to improve fastness of models creation. To achieve the referred goals, it is required an automation of all standardizable operations involved in the process of models generation. In this system it is proposed, precisely, the automation of crucial aspects for fastness and user intervention minimization which involves information extraction and procedural generation of buildings facades and interiors.

The extraction of relevant data from several different sources will provide the necessary information to be processed and represented by the modeler. The resulting information is interpreted and converted in formal grammars based on historical architecture expertise. Formal grammars provide a set of rules which guide the process of expeditious generation. With the inclusion of both features, information extraction and procedural generation, it is intended to propose a system to aid archeologists’ researches by producing enhanced virtual reconstructions of archeological sites. The general architecture, presented on Fig. 1, is composed by two main functional modules which are closely related with the previously mentioned goals: an information extraction module, a procedural generation module.

3.1. Information Extraction Module

The Information Extraction module will be responsible to produce rules from several sources such as geospatial data and textual descriptions. The extraction process will rely on an ontology that will be based on architecture and archeology domains’ semantic and architectonic styles knowledge. The mentioned ontological data structure supports ERAS’s domain with the objective of eliminating ambiguities and adding semantic information to the present model. Ontology must also deal with cultural and age styles. Moreover, it constitutes a shared vocabulary that should be used in conjunction with the textual descriptions to decode the production rules. This production rules can be subdivided in two kinds of guidelines for generation. The first one, ontology-based populated data schema, can be seen as a structured data model generated accordingly with the ontology. It contains the required data extracted from the information sources. On the other hand, there is a data structure used to control the generation process, the rules. The main objective of this complementary data schema is to force the generation process to obey to architectonic restrictions.

In a previous work (Rodrigues et al.), a first approach allowed the generation of simple 3D models based on a textual description. Now, it is intended to refine this methodology to improve the detail in the models that will be generated under this system. In order to accomplish this improvement, the Information Extraction module will integrate the GATE ("General Architecture for Text Engineering") which is a free configurable system to extract information. GATE has to be configured to work properly for ERAS domain and ontology. After these adjustments, the extraction module is ready to extract the guidelines for virtual generation. These rules, as the ontology data model, can be edited using a user interface and it can be seen as a style sheet for procedural generator, in which are defined the architectonic constraints and also the default data to bridge possible lacks of information.

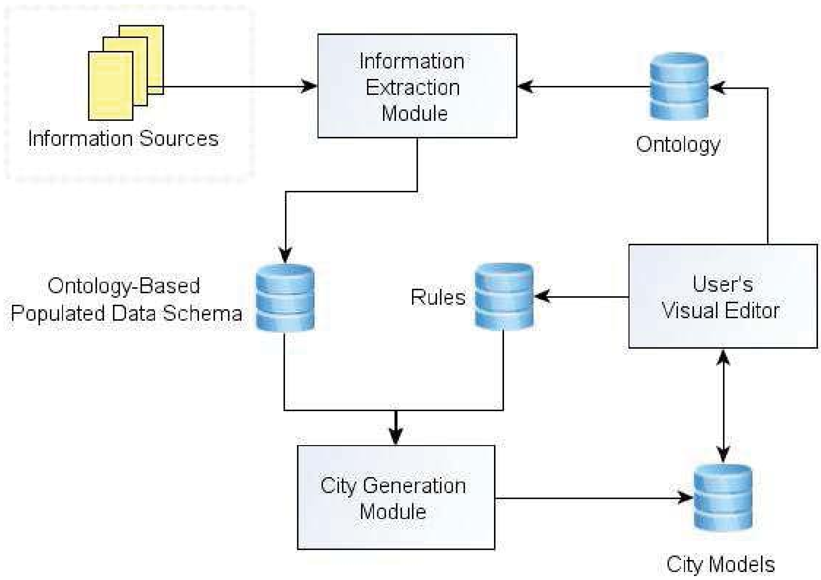

Fig. 1 Architecture of ERAS, composed by two modules: the information extraction module that acquires the information relevant and determines the production rules and the Procedural Generation module that constructs the 3D model of the city based on rules

3.2. Procedural Modeling Module

The module that generates the archeological site's virtual model is the procedural modeling module. The generation of virtual models using procedural modeling techniques was applied previously on urban and archeological environments focusing mostly the generation of building exteriors, as it was mentioned in background section. In ERAS, one of the most challenging tasks will be the creation of a new methodology, capable of deriving production rules based on a solid ontology to achieve generation of detailed archeological sites with traversable buildings. The expected rules will guide the site generation, by providing instructions about arrangement or style, employing procedural techniques derived from the classical ones, such as L-System or CGA Shape technique.

The procedural modeling module is planned to generate models in a few stages. Firstly, the outdoor elements (such as streets) and buildings are sequentially generated. The generation of buildings produces exteriors and interiors. The exteriors, at this point, define simple facades, external shape and dimension of the building and can also be seen as the containers for the rooms. In the other hand, the interiors define the rooms of the building with connection points to its exterior (doors and windows) and its internal facades, shape and respective placement. These rooms are expanded to proper fit the exterior. Finally, the inner and outer facades are detailed, using a procedural technique to achieve it. This generation steps will result in a complete and detailed model of the archeological site requested.

4. ERAS Information System Specification

In this section it will be presented a specification for ERAS. Firstly it will be presented an elicitation of functional requirements with the respective use cases. The requirement analysis will show the range of tasks that an archeologist may perform by presenting explicitly the requests that can be made to the system on a use-case diagram. In the same line of reasoning, it will be addressed the sequence of operations that will occur in the system from the user requests to the model generation. In here it will be represented the behavior of the system using a sequence diagram that intends to show the order of the user requests and system responses. At last, the high level static structure of ERAS will be shown in a class diagram in where can be observed the intervening elements and the relationship existing between them.

4.1. Functional Requirements

The proposed archeological tool to generate ancient cities was thought to satisfy certain requirements. These requirements are related with the range of operations that an archeologist may achieve. Therefore, a user can submit information sources to feed the system, such as geographical data or textual descriptions. This implies the selection of the sources set, which can be in several different formats, and the upload of this set. The system receives the submitted sources and extracts the relevant production guidelines. They both may be edited by the user in order to: (1) redefine the rules that support the 3D model generation according to the architectonic style in use; (2) bridge insufficient information or to choose a study focus, for example, a user may just be interested in observe the temples of an ancient city. At last, the user may request the model generation. The system optionally allows user to save the model in a proprietary format or in a standard format (such as X3D) and also allows the interaction with the generated model, mainly to select features, manipulate it and navigate through the city. The user can select a city element and modify its proprieties (size, position, textures, etc.). These operations always reflect the changes in the data structure that feeds the procedimental generator. In order to demonstrate the referred functionalities, it was designed a generic use-case diagram (Fig. 2) that explicitly presents the main tasks available.

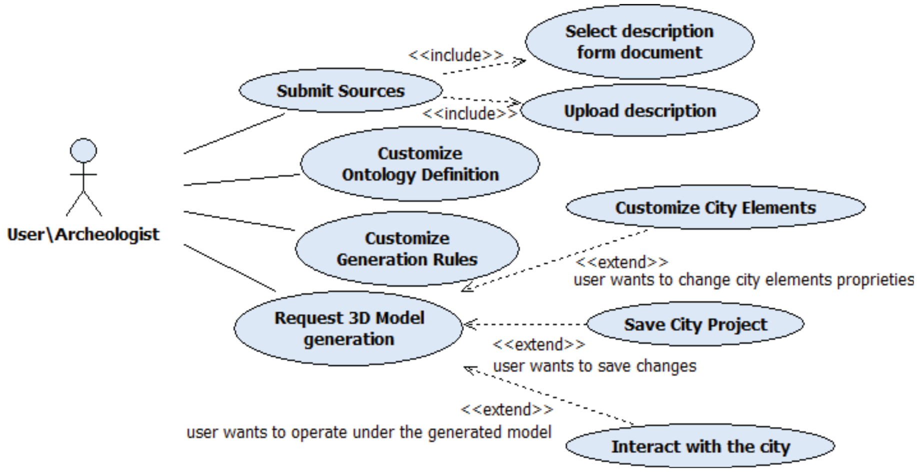

Fig. 2 Use Case Diagram illustrating the range of options available to an archeologist

4.2. Operations sequence for 3D model generation

The sequence of the operations occurring in the system, shown on Fig 3, is a convention that establishes a natural order for the tasks. In this case, the focus is the sequence of operations since the user submission of information sources until the model generation, which we consider as the most relevant part of the system behavior in this specification stage. Thus, user is the entity that starts all the process. The first operation is the trigger and happens when user wants to produce a 3D representation of a city, based on some sources of information. Thereby, user submits the information sources to the procedural modeling module. The module gets the sources and invokes the Information Extractor. This component is responsible to derive all the generation guidelines from the received sources based on the ontology that owns the significance and semantics needed, according to an architectonic style. During the process, the ontology is also useful to deal with lacks of inexactness of the terms. The extraction process is performed in a loop that lasts until occur the parsing of the last source. After completed, the set of production guidelines returns to the Procedural Generation as a result. These guidelines are not more than a populated data schema based on the ontological data model. At this point, the user can modify the rules that define the restrictions and default patterns according to the architecture in use. The redefinition should satisfy its study focus, or even an expert point of view about architectonic specifications. After a rule confirmation, the user can request the 3D model generation. The procedural modeler reads each guideline extracted previously by the Information Extractor module to produce a 3D model, including buildings with exterior facades and internal divisions. The generation is guided by the set of rules in order to provide a consistent and credible model, avoiding awkward occurrences, for example, the generation of buildings upon the streets. Lastly, the model is rendered to the output device with the objective of presenting a full and detailed 3D visualization.

4.3. Information System Static Structure

The static structure of a system can be represented by a class diagram (Fig. 4). This representation intends to show the relationships between the acting entities and the services provided by each one.

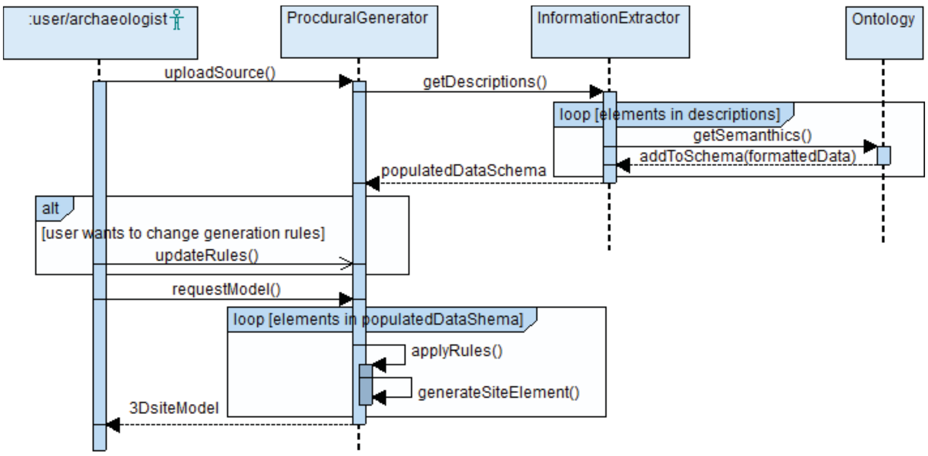

Fig. 3 ERAS's sequence diagram representing the order of operations from the user source submission to the 3D model generation

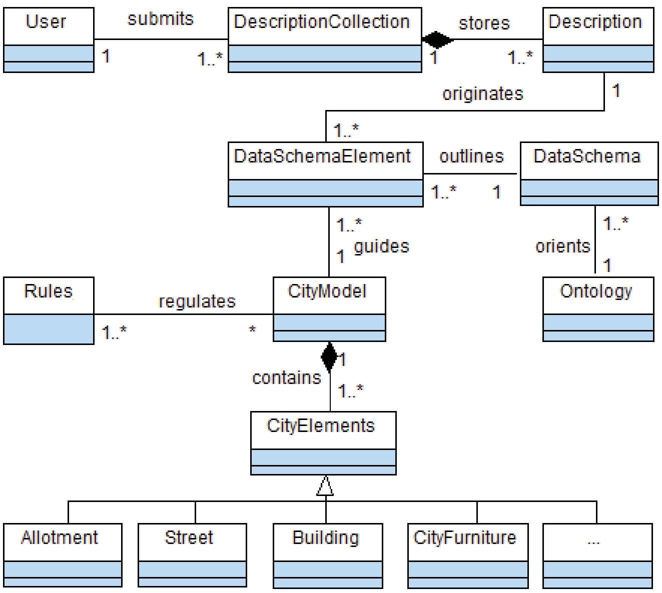

Fig. 4 Class diagram representing the objects of the ERA's system and the services exchanged by each one, from an archeologist request to the city generation process guided by rules extracted from a set of submitted descriptions.

A class diagram suggests a structure that defines a set of connections between the system entities. In the case of this project the main entities are: user, ontology-based architectonic elements (extracted from descriptions), rules and city. From the point of view of the object-oriented paradigm these are the entities that perform the necessary actions to provide a virtual reconstruction. The classes are also responsible of carry data needed to produce valid outputs. From the point of view of the data model, the entities can be seen as tables that store the persistent data in a database responsible to save and maintain the projects and to feed the procedimental modeler when a city previously generated is accessed. Basically, this data model proposes a relationship schema in which can be identified the user as the element who triggers the generation process, the set of documents used to extract information, and the resulting guidelines (populated data schema) and rules applied to guide the city generation process.

The class diagram of ERAS was planned to deal with the data involved in the generation process triggered by an archeologist request. Thus, a user, as the entity representing the archeologist, may submit a collection of documents, composed by, at least, one descriptive document. An information extractor pulls the architectonic elements to a structured data schema, which stores, for each description, at least one guideline to accomplish the generation of the city elements. Information extractor can be seen as a functional module to interpret descriptions using an ontology and determining the formal guidelines required to an automated generation. On the other hand, the generation process is also guide and restricted by the production rules. These rules should be used by the procedural modeler in order to generate all the virtual elements accordingly with the architecture style in use. The system includes the customization of the rules, hence a user can modify one or more of this rules. When these rules are finally established, the user can request and save a city model. The resulting models are composed by several city elements such as streets, allotments and buildings which are equally stored in the database; however they can be changed on the fly by a direct user's manipulation on the visualizer.

5. Conclusions and future work

In this paper it was presented the specification of a new information system to generate archeological sites expeditiously. This system, called ERAS, is intended to be a useful tool for archaeologists and public in general, capable of recreate enhanced virtual environments describing lost places of ancient ages.

The presented specification provides future directions for development, which will also take in account the work previously done. Thus, some improvements and extension have to be made on those works to guaranty a reliable integration of such features (e.g. textual processors or production rules definition) in ERAS. Moreover, it is intended to define a solid ontology to deal with architectural semantics for the styles defined for this project. Finally, it is needed an extra effort to create a new methodology capable to hold the generation of building interiors and building facades, with various geometric shapes and high accuracy.

Acknowledgements

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