A Procedural Approach to the Modeling of Urban Historical Contexts

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The demands of modern computer graphics in the field of cultural heritage call for the use of extremely complex models, often containing millions of primitives to recreate entire and complex historical urban environment. Using a procedural approach in architectural modelling, we can recreate virtual cities constructed by automatic procedures that make use of randomness for variety and credibility. The generation of structures, based on algorithms and procedures to generate models is particularly functional for the extensive archaeological landscape reconstruction in comparison with other computer graphic techniques because it allows a global reinstatement of the site and gives an immediate perception of the ancient urban context and landscape.

Keywords: Procedural, Parametric, Modelling.

1. Introduction

This paper analyses the approaches commonly adopted in the reconstruction of archaeological landscape and urban contexts. Methods, software, and data required by these approaches are underlined. Possible outputs (still images, GIS, webGIS, computer-graphic movies, real time applications) obtained by following these methods are also shortly described. The paper underlines how issues and problems regarding the reconstruction of our past, such as the management of uncertainty, should be faced with a new and deeper awareness. Procedural modelling is described and referred to the definition of new ontologies. New results might be obtained through the procedural modelling of ancient territories in different realms: in the research and also in the definition of a new modelling process.

2. 3D acquisition and modelling of monuments

Different methods are traditionally employed to model architectural elements and monuments, according to the level of detail and the required documentation: 2D architectural plans and sections with CAD tools, photogrammetry and laser scanner techniques. In the first case the obtained models are correct in terms of general dimensions and typology, but they cannot represent the exact topology of the object, because they do not come from a process of high resolution topographical acquisition. On the other side, photogrammetry and laser scanning are usually employed in order to document and represent in 3D the real topology of the object with a high level of detail.

Photogrammetry is an image-base technique that allows to obtain reliable information about physical objects and the environment through the process of recording, measuring, and interpreting photographic images. Since it turns images in a textured 3D model, a great number of pictures and corresponding points are required for processing a detailed and complex object, with is considerably time consuming.

Laser scanning, a range-based technique, is able to acquire an object as a set of point clouds, with very high precision. The post processing work, aimed at creating a meshed model with the proper level of detail, includes many phases of elaboration and optimization and it is often long and tedious. The final result is a high resolute model documenting, very precisely, the object surface and its condition of preservation.

Therefore photogrammetry and laser scanning are useful techniques, if we need a "monographic" survey of the object and a detailed topographical documentation. Their limit is represented by the fact that only visible parts of the objects can be modeled. There are always some parts or elements that cannot be captured by the camera or the laser and that need to be reconstructed trough similarity, if possible.

Furthermore both techniques produce "monolithic" models (especially when photogrammetry is applied with an automatic calculation method) representing the entire topological surface of the object, without any "semantic" characterization. There is no distinction among roads, buildings, walls, roofs, windows, doors, gardens, trees: all is included in a unique whole object deriving from the triangulation of the point clouds; division and characterization had to be made by hand. This result is obliged and due to the laser scanning approach.

In this condition no further use of the models or changing of their parameters becomes possible in successive projects. A building includes many architectural elements: floors, walls, openings and roofs, balconies, cornices, columns, vaults, cupolas, sculptured elements and so on. Also each architectural element can be, by itself, a complex object. It can be a compound of elements. Another factor of complexity is the number of building required to create a given urban environment.

In the field of archaeology, laser scanning and photogrammetry techniques are usually applied in order to document and reconstruct the actual, observable state of conservation of artifacts, but they can also be used for the reconstruction of the ancient appearance of monuments, objects, landscape, starting, for instance, from the acquisition of plastic models (FORTE *et al*., 2008).

According to us, the reconstruction of holistic and complex urban environments can be successfully obtained using parametric and procedural modeling. Procedural modeling is not an innovative method , the innovation consists in the use that can be given infor study of archeological landscape.

3. Procedural modelling

One of the main targets in virtual archeology is to recreate large and complex ancient urban environments,

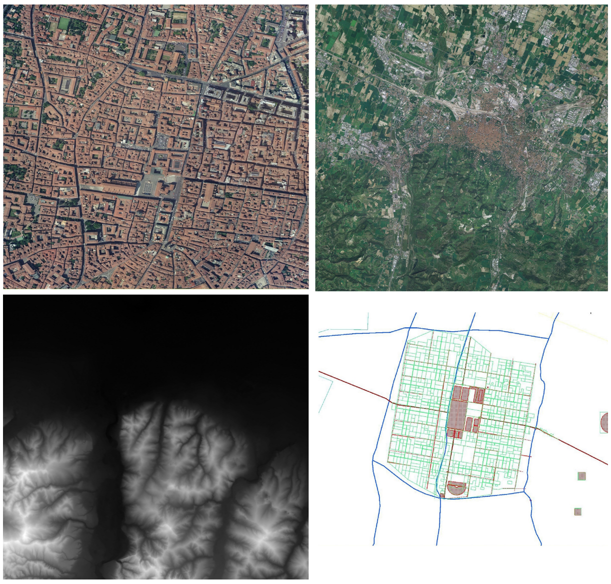

Figure 1: *Initial data for the reconstruction of roads and roman "centuriatio": Archaeological GIS of Bologna, aerial photos, Digital Elevation Model.*

but it is not easy in its realization. In fact the creation of several and different buildings type, requires huge resources and a long execution time with traditional computer graphic techniques, and often the problem is solved just by reconstructing the most relevant buildings, which are deprived of their original archaeological context. Procedural modeling is particularly useful for a large distribution of buildings. In fact this technique makes the creation of complexes urban environments easier in comparison with other computer graphics methods. (MUELLER *et al*., 2007).

We decided to use this technique to recreate the urban extension of the city of Bologna during the roman age (I century A.D.). Although we cannot have a complete and detailed knowledge of the Roman structures of "Bononis" we can simulate a potential model of the city. This work has been carried out within a wider project, coordinated by the CINECA (supercomputing center), aimed at creating a short CG stereoscopic movie on the history of the territory and the city from the 9th century BC to the restoration. This movie will be shown from, 1992 in the new City Museum. Our activities regarded the virtual reconstruction of the city and territory during Roman and Etruscan times, applying procedural techniques and starting from archaeological data.

Procedural modeling uses different techniques: image based, L-Systems and parametric rules. The urban environment creation starts from geospatial and topographic data (GIS and CAD), which can be associated with elevation maps, distribution maps, density maps etc, for a correct representation of the geographical profile. In the reconstruction of Bologna we have combined the Roman "centuriatio", the archaeological map, the aerial photos and the street map with the digital elevation models of the city (fig. 1).

Afterwards the building lots are generated on the base of these imported shapes. The generation of the different typologies of buildings is defined through a scripting language, rather than the traditional editing tools, using a shape grammar approach based on alphabet and symbols which describe the geometry of the models. The models are described in progressive order through additive processes. In every step wideness, parameters and relations are defined with the existing entities. This allowed a complete control of the entire project: changing a parameter that stands at the top of the scene hierarchy, we can modified all entities allied (fig. 2).

After programming the script that describes the entities, it is associated with the building lots and the virtual geometry is generated automatically by the software (we have used CityEngine).

The biggest factor of complexity is the number and the different typologies of buildings required to create a plausible urban environment. Using a shape grammar approach we can defined the variables employed to generate different versions of the models and to accelerate and automate the modeling process. These

Figure 3: *Different building generated by a single script. The script contains the rules to generate different styles of roman temples according to the user needs. Changing some parameters (as columns styles, number of columns, height of the "podium", slope of the roofs etc) the software generates a new model of buildings. The models could be reused in an unlimited number of cases.*

variables can be created on causality, similarity and repeating criteria.

In our case they were particularly useful to simulate the distribution of buildings because variables allowed to introduce some modifications on elements with similar, but not identical, properties that repeat themselves in space. In fact we used a few built patterns to model entire portions of the city and to create different versions of the models which were generated randomly by the software (fig. 5). These modifications can be managed

```
//-------------------------------------------------------------------------------------------------------
//Geometry

//definizione della base
Lot-->
case tipo_monumento
== 1: COLONNA
else: PODIO
COLONNA--> extrude (Livello_citta) comp(f) { top : piano1 }
piano1-->split(x) { {~1:NIL | largh_plinto : Basemonum} | ~1  :NIL}
Basemonum-->split(y) { {~1:NIL |largh_plinto : cubo} | ~1  :NIL }
cubo-->extrude(4)split(y) {0.6 : base|0.3:cornice|2:plinto|0.3:cornice|0.5:basecolonna|0.2:areacolonna }
cornice-->s(largh_plinto-1,'1,largh_plinto-1)center(xyz)comp(f) { all : pietra4 }
plinto-->s(largh_plinto-1.5,'1,largh_plinto-1.5)center(xyz)comp(f) { all : pietra4 }
basecolonna-->s(largh_plinto-2,'1,largh_plinto-2)center(xyz)comp(f) { all : pietra4 }
areacolonna-->s(largh_plinto-2.5,'1,largh_plinto-2.5)center(xyz)
            comp(f) { side : latibase|bottom:basestatua|top:colonna }
            latibase-->pietra4
            base-->comp(f) { all : pietra4 }
colonna-->extrude(alt_colonna)col
col-->case LOD == 0: comp(f) { all : colonne2 }
            else :i(Colonna)comp(f) { all : colonne2 }
basestatua-->case Statue == 1: constatua
            else: comp(f) { all : pietra4 }
constatua-->t(-0.1,-0.2,-alt_colonna-0.1)extrude(-0.1)
comp(f) { top :statuaA|all:NIL }
statuaA-->i(Statua)r(0,0,270)center(xy)comp(f) { all : pietra4 }
//-----------
PODIO--> extrude (Livello_citta) comp(f) { top : piano2 }
piano2-->case Monumento_su_podio
            ==1 : SENZA_RECINTO
            else: CON_RECINTO
SENZA_RECINTO-->
split(x) { {~1:NIL | largh_plinto2 : Basemonum2} | ~1  :NIL }
Basemonum2-->split(y) { {~1:NIL |lung_plinto2 : cubo2} | ~1  :NIL }
cubo2-->extrude(4)split(y) {0.1 : base1|0.7: base2|0.1 : base3|0.1:base4|alt_plinto:plintoB|0.1:base3|0.1:base2|0.1:base5|alt_altare:altare}
  plintoB-->comp(f) { all : pietra4 }
base1-->case LOD ==0: comp(f) { all : pietra4 }
          else:s(largh_plinto2+1,'1,lung_plinto2+1)center(xyz)comp(f) { all : pietra4 }
base2-->s(largh_plinto2+0.7,'1,lung_plinto2+0.7)center(xyz)comp(f) { all : pietra4 }
base3-->s(largh_plinto2+0.5,'1,lung_plinto2+0.5)center(xyz)comp(f) { all : pietra4 }
base4-->s(largh_plinto2+0.3,'1,lung_plinto2+0.3)center(xyz)comp(f) { all : pietra4 }
base5-->s(largh_plinto2+0.3,'1,lung_plinto2+0.3)center(xyz)
    comp(f) { top : pianoara|all:pietra4 }
```

Figure 2: *An example of script that controls the generation of buildings.*

and distributed in the scene either in automatic mode, by the software, or manually, by the user (parametric mode): to create the mass models (as domus, insulae, tabernae, etcetera), for which we had no information on their size and precise location, we adopted an automatic approach, in a way that the typologies of individual building have been randomly distributed (fig 5)

To create specific buildings, with size and position are known (as excavated temples, basilica, macellum, porticus duplex, theatre), we preferred the parametric mode. With this technique, 3D models can be modified through parametric control tools and can be used based on archeological data (fig.4).

To create the temples, for example, we have included different information about roman styles in the script, and have attributed the script to the temples as appropriate .

To create complex architectural elements, we imported into the scene also 3D models created with other computer graphic software (as columns, statues, sculptured elements, cornices, and so on) to give some buildings a specific characterization . These external elements were associated to the models as instances to supplement or replace the elementary geometry reference. In this way we could have, in a single script, different levels of detail which allow easy management for our different destinations: film and real-time applications.

Finally we export the scene to most popular formats (3ds, obj, collada) to perform the rendering in dedicated softwares (fig. 9-11).

We also used this technique to store all built digital models into digital libraries and create an architectural database. We feel digital libraries a fundamental need, in fact we could reuse these models in other successive projects with great time saving. Many parametric objects are available in digital libraries for specific fields (industry, mechanics) but there are still few examples dedicated to architecture and Cultural Heritage. Procedural modeling from architectural rules is a very promising field of research. These concepts are strictly connected to the emerging research in the field of semantic 3D media (DE LUCA *et al*., 2007).

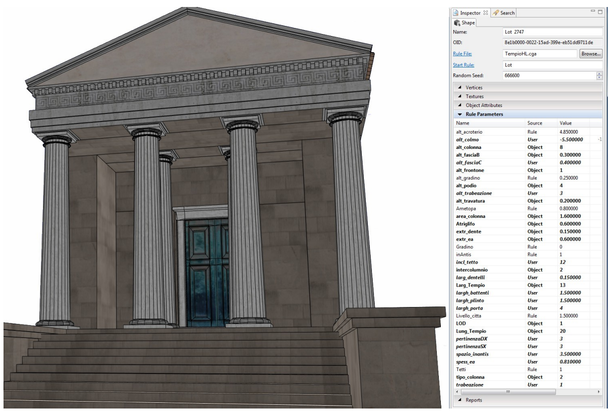

Figure 4: *Parametric controls for interactive changes. This techniques is used, after realization of the models, to update or change the geometry.*

Unfortunately the software used in our software such as others are focused on architectural building while it would be very interesting to extend this approach also to natural elements. In the described project, in fact, we had to use another way to model vegetation. We chose Visual Nature Studio in order to reconstruct the natural environment with related ecosystems around the city of Bologna, starting from the same GIS dataset used in the procedural modelling activity. Thanks to VNS, we have been able to manage raster and vectorial data including the correct representation of Roman agricultural lots subdivision (“fundus”, “campus” and “iugerum”) and to finally obtain a 3D model of the potential ancient ecosystems and landscape (fig. 7). This geographical approach employs geographical data for the modeling, and has made possible a perfect integration between natural and architectural models.

After this project we will extend our research in this interesting approach.

Conclusions

The reconstruction of holistic and complex urban environments can be successfully obtained using parametric and procedural modeling. This methodologies allow to create 3D models that can be very detailed even if not representing the effective, detailed topographical characteristics of the object.

3D elements/buildings that can be modified through parametric controls can be reused in an unlimited number of practical cases and successive applications, according to user's need, with a significant simplification and reduction of time .

The need of creating and sharing digital libraries, especially through the web, is a fundamental subject of the cultural debate in Europe. Procedural modelling from architectural rules, keeping in consideration also old treaties from ancient and classic authors, is a very promising field of research: the knowledge of the context scheme is very important to place each piece of the puzzle correctly and in relation to its neighbors.

In 1977 James J. Gibson introduced the term “affordance” in his article "The Theory of Affordances"; in 1979 he explored it in deeper way in the famous book “The Ecological Approach toVisual Perception”. He defined affordances as all "action possibilities" latent in the environment, objectively measurable and independent from the individual's ability to recognize them, but always in relation to the actor and therefore dependent on his capabilities. The physical aspect of an object allows a user to understand the principles of its functionalities. For instance a set of steps afford the act of climbing, or the aspect of a handle affords the way of opening or closing a door. The concept of affordance does not belong to the object itself, neither to the actor, but spread from the relation established between them. We could say that it is a “distributed” property. What we perceive when we look at objects are mainly their affordances, not their dimensions and properties.

This approach and these concepts are strictly connected to the emerging research in the field of semantic 3D media.

Even if we have many tools for visualizing, streaming and interacting with 3D objects, tools for coding, extracting, and sharing the semantic content of 3D media are still lacking. The definition of geometric primitive entities together with their semantic characterization, through associated meanings, represents a new research line that can be extremely useful to support a stable and standardized approach to content modelling and sharing. Through this new modeling paradigm, it is possible to formalize the geometry form of an object (geometric model) together with the set of contexts that could use this model (semantic model). (FALCIDIENO, 2008).

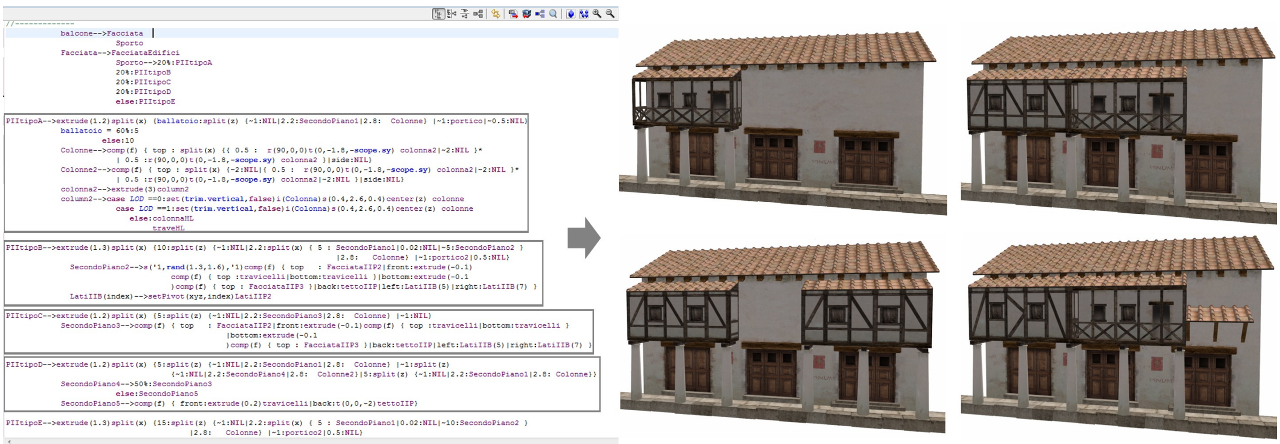

Figure 5: *Some simples model (low level of detail) generated by automatic procedures that make use of randomness to add variety. In this case a single built pattern was used to model large portions of the city: The aspect of buildings depends on dimensions; the height is assigned by the software on casualty criteria in a range previously decided by the user and based on archaeological in-formation.*

References

ANNUNZIATO M., PIERUCCI P.: Emergenza e biodiversità della forma: l'estetica dello scambio tra vita reale ed artificiale, in "Sistemi Intelligenti" (Il Mulino), Anno XVIII, n. 1, April 2006.

CHEVRIER, C. AND PERRIN, J.P., 2008. Interactive parametric modelling: POG a tool for the cultural heritage monument 3D reconstruction. *CAADRIA conference*, Chiang Mai, Thailand, April 9-12 2008, pp.487-493.

DE LUCA, L. AND VÉRON, P. AND FLORENZANO, M., 2007. A generic formalism for the semantic modeling and representation of architectural elements, *The Visual Computer*, Volume 23, number 3, pp. 181-205.

FALCIDIENO BIANCA, 2008. "From Geometric to Semantic 3D Content: The FOCUS K3D Initiative" in *proceedings VSMM 2008*, Limassol, Cyprus October 20th-25th 2008.

FOCUSK3D http://www.focusk3d

FORTE M. e AA.VV 2008. *La Villa di Livia, un percorso di ricerca di archeologia virtuale*, ed. Erma di Bretschneider, Roma.

GML 2008. http://www.generative-modeling.org

JAMES J. GIBSON, 1979. *The Ecological Approach to Visual Perception*.

MUELLER P, ZENG G, WONKA P AND VAN GOOL L, 2007. Imagebased Procedural Modeling of Facades, ACM Transactions on Graphics, volume 26, number 3,article number 85. pages 1-9. *Proceedings of SIGGRAPH* 2007.

RYAN M.L., *Narrative as Virtual Reality: Immersion and Interactivity in Literature and Electronic Media*. Baltimore and London: Johns Hopkins University press, HB, pp. 399, 2001.

Figure 6: *The roman "Basilica" in the workspace. The model was generated at high level of detail with procedural technique. Architectural details, as columns, statue, pillars and friezes, was imported form Blender software.*

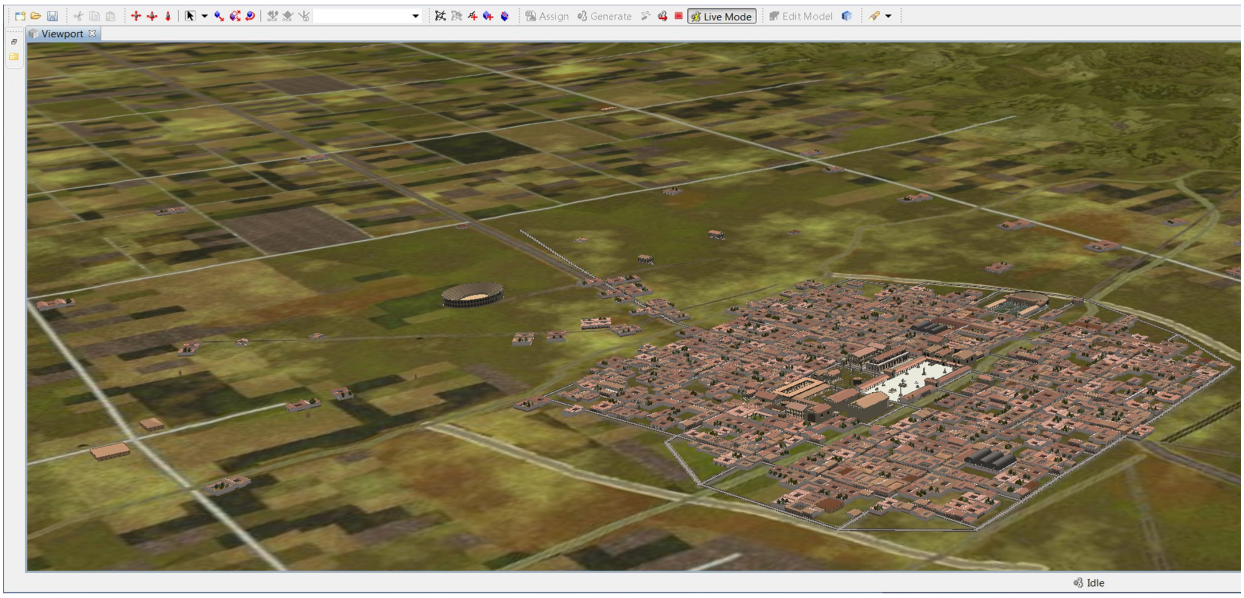

Figure 7: *The procedural city of Roman Bononia displayed in CitEngine.*

Figure 8 - 9: *Examples of reconstruction through procedural modeling of the Roman city of Bologna and its territory.*

Figure 10: *Top overview of the reconstructed Roman city of Bologna (shot from the movie).*

Figure 11: *Example of complex buildings modeled in CE with detailed external assets made with Blender (shot from the movie).*