Data Organization in City Modeling

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Abstract. Working with big models requires a good balance between the technical requirements of the model and the technical requirements of the user. Although every virtual model, whether it is 2d, 3d or 4d, may be regarded as a particular form of a general data base, it is clear that is not, at the present time, a very flexible data base. It does not behave like a relational data base that can be inspected in a flexible way. On the contrary, it has a rigid structure, a hierarchical structure that is well suited for performance but is badly suited for navigating through the data and gathering derived information. These are well known disadvantages and advantages, related to the evolution of the data base software that has moved, in the last 30 years, from a hierarchical to a relational structure.

These considerations are relevant for any kind of architectural or engineering model. But are particularly pertinent in the case of the model of a city where everything must have its place, and should relate properly with other parts of the model, be susceptible of further modifications and be able to receive new information. These and other related issues have been encountered and developed during the construction of several models at our Laboratory at the ETS Architecture of Barcelona. Our paper explains the main decisions we had to take during the course of these works with special emphasis on those aspects related with the organization of different kind of data in a unified whole that had to be sent to other professionals and had to be, for that reason, organized in a clear and comprehensible way for its further development.

Keywords. CAAD; City Modeling; Visual Simulation.

Introduction

Data organization in CAD and CAAD systems is a well know topic and it is a fundamental part of what is currently known as “computed aided design”. Many industrial products are created in such a way that there is a continuous stream that goes directly from the first design models to the final real object, using CAD/CAM systems. This means that, at every stage, data should be organized in such a way that facilitates the conversion from one method to the next. This has been going on, since many years ago, whenever the object designed is of such a kind that there may be thousands of objects based on a single and well studied prototype.

Although many attempts have been made to bring these kinds of procedures to the architectural world it is evident that they have not succeded; and it is doubtfull that, in some cases, they will succeed, for quite a long time. The main reason is that architecture is not based on repetition but on singularity. First, it is anchored to a particular site and, second, professional fees are based on the originality of conception. These two reasons are enough to hinder most attempts to bring the above mentioned methods to the production of architectural artifacts although the elements of which buildings are made-of may benefit of these industrial production advancements. But there is still another well known reason that explains why it is difficult to export the kind of data organization that has been developed in other fields to the architectural scenario. Industrial products are made of parts that can be clearly separated. Architectural products do not. They may be subdivided in different ways and by very different reasons.

It is true that some very interesting proposals have been made to incorporate different interpretations of a single data. There are very well known papers from Mitchell or Stiny that include very pertinent remarks on this topic and propose stimulating lines of research. But nonetheless it is true that attempts to implement this into CAAD systems leads to complicated and non practical systems.

If we bring this discussion to the field of big architectural models many of the questions reappear in another form. Although many developpments have taken place in which 3D models are connected with Geographical Information Systems and 3DGIS is becoming a powerful reality, there are still many problems and many inconsistencies to be solved.

We think that the data organization of big architectural models, even from the point of view of their pure visualization, has not yet reached a sufficiently mature state as to provide a solid link with more complex information systems. There are still many different approaches and technical problems that deserve further discussion. We hope that this paper, as it is based in the developpment of quite a few projects that have implied the modeling and organization of big amounts of data, including more than 1 million faces, may contribute to this discussion.

Our experiences with big models

During the last 3 years we have developped a few models as part of the current work of our Laboratory, the LMVC (Laboratorio de Modelización Virtual de la Ciudad) that aims at building a general model of the main parts of Barcelona as other cities have done. The Laboratory has two main areas: The Modeling Area is directed by Javier Monedero, the GIS Area is directed by Pilar Garcia Almirall; both of them teach and direct research studies at the ETSAB. The general coordinator is Josep Roca, Department of Construction professor at the ETSAB. Francisco Muñoz is in charge of the general functioning of the Laboratory and collaborates mainly in the modeling area. Recent collaborators, also in this area, are Andreina Linares, Andrés Lupiáñez, Marc Pujol, Carolina Ruiz and Héctor Zapata.

As this Laboratory is self financed we have been involved in many modelling projects, most of them for public institutions. Some of them have been crucial to analyse the problems implied in the development of city models or, in general, big architectural models. The main projects we have been recently working on are the development of models for the old city of Cadiz in the XVIII century, the new area of the Forum 2004 in Barcelona and the reconstrucion of the city of Barcelona at the beginning of the XVIIIth century. The figures at the end of this paper show some images from these projects.

The city of Cadiz, where was located the port from where the ships that went and came from America, loaded with silver, among other goods, was one of the richest of Europe at the beginning of the XVIIIth century, due to its privileged position. At some moment during this period it was decided to build an enormous wooden model (with marble in-betweens) that remains in a big room surrounded by a corridor to allow visitors to have a proper view of the whole model. In 1999 the City Hall of Cadiz decided to replicate this material model with a virtual model. Our Laboratory received the assignment of carrying out that job which we did between October of 2001 and may of 2002. This model was to be used as a basis for further work which would include characters, films, virtual reality and the like. The model represented an extension of about 9 km2 and 600 buildings.

In April 2002 we were offered the possibility of building a virtual model for what is, at the moment, the main development carried out in Barcelona since the Olympic games: El Forum de las Culturas, to be open in 2004. It intends to bring together different institutions and organizations to discuss a variety of issues concerning ecological, sociological, cultural and political aspects of world wide interest. The job was not only to show many relevant buildings, designed by well known architects (Herzog and Meuron, Zaera, Mateo, Miralles or Bru among others) before they were actually builded. Even more important, due to the actual state of the works, with many parties involved and still many questions to be solved before the final phase, was to have a model that might be walked around interactively by participants in the process, professionals or not, and that will allow them to have a clear grasp of a big (about 2 sq Km) and complex site with different levels and winding paths.

The last of these projects (still in progress) is a job to build a model of Barcelona, in beginning of the XVIIIth century, when the city was still surrounded by big walls.

The hardware used for these projects are several PCs, around 800 MHz, with 512 ram, 128 vram, a 3d scanner, etc. To prevent disasters we film separate frames, borrowing PCs from other departments. Then we put them all togeher using Adobe Premiere and Macromedia Director. The usual modeling software is AutoCad and 3Dstudio. We rather use big textures that we try to keep regular, following BOT (block ordering textures) requirements. Sometimes our models are transferred to Maya that we are also starting to use. The interactive navigation is done with current navigators (like Cosmo or Cortona) and Alice, a system produced by our university. The resulting models are also shown at the UPC CRV (Centro de Realidad Virtual) that has got a 3_3_3 cave, among other things.

Different intentions. Different data and organization systems

A model is an abstraction. Therefore, to prevent misunderstandings, it must be clearly stated, from the beginning, what is abstracted, i.e., separated, erased from the original. This is still more necessary in computer models, as they are more rigid than traditional models, a limitation that, as we said before, has been the object of many research papers in the last few years. It is true that, as these papers remark, traditional drawing lines can mean different things and this rich ambiguitiy is something that should be recovered. Or to put it another way, that CAAD internal data bases should become relational rather than hierarchical. But a relational database is still a model and, as such, an abstraction that is guided by sense, by intentions. Consequently, if the intentions vary, the selected data will be different and the organization system will be different as well.

If a model is intended for visualization, only the skin is needed. This can be used, or not, for general information if the skin closes around a particular piece of information (i.e. a building or a particular part of the city) which may not be the case. If it is intended for performance analysis, only the elements implied in a particular function will be needed, and this may not include the skin in some cases, like in structural analysis. If it is intended for production, every element must be modeled with the required precision. In all theses cases the data organization will be different as will be the criteria by which it is organized.

We have tried different ways to organize the models we have been working on. At the end, we have found that what sometimes is considered as the simplest model of all, the visual model, which stands usually at the beginning of the whole process is, perhaps, the most complicated of them all. Or that, in any case, many aspects have to be discussed since there is not a unique way to develop this kind of model.

Three scales, three methods

Throughout the last models we have been working on we have used three different methods of representation. The first follows a homogeneous procedure in which the whole model is based on a regular grid. The second is a mixture of the first and the third. The third follows a heterogeneous procedure in which the organization is dictated, to some extent but not completly, by the singular buildings included in the model. These three methods must be related in some way.

The first method is based on the projection of carthographic bit maps upon a DTM (digital terrain model). This implies the existence of a DTM and correlative photographs of the area covered by it. The territory is divided evenly. The main data are rectangles with two UTM coordinates that represent the upper left and the bottom right corners so that WN (x1,y1) and ES (x2,y2) would represent a piece of land of (x2-y2) by (y1-y2) meters. The z coordinate is given by the DTM model in each case through an appropiate software that can also be used to export the polygonal mesh to a modeling program like 3DStudio. These rectangles are related with bitmaps in such a way that the resulting scale (in our case) was 1 pixel = 2.5 meters.

As the figure 1 shows, this is enough to get a good representation of big models seen from a long distance. If we get closer, we can jump to ad hoc models that may incorporate extruded models of buildings and combine them with parts of the DTM model, and we can also use bigger bitmaps. In this case, different bitmaps may be used, combined with LOD techniques in such a way that we can get a multirresolution representation with values that can go down, in some cases to 1 pixel = 50, 20 or 10 cms. There are, however, a number of technical problemas, related to the way that our geometric grid is subdivided to match the bitmap grid. This issue would deserve further discussion in a longer paper.

Up to this we are working with an xy plane divided homogeneoulsly and with a unique projective direction (z projection). As we get closer to the buildings, we reach a situation where projections must be produced in the xy plane as well.

So the third method can be considered as an unfoldment of the other two. In theory, we could follow the same method: a digital model where every xyz coordinate will receive an rgb value (like in a procedural map). But of course this is, at the moment, not possible, thus other considerations have to be introduced.

A pure visual model. Is it so simple?

Our model is a visual model. This means that the city is conceived as a continuous surface or as a multifaceted layer with zero thickness. Therefore there are, properly speaking, no elements such as walls and windows or staircases. Neither is there an organization dictated by different materials, as many buildings or parts of buildings are modeled with ad hoc textures, that is, complex textures that incorporate different materials. Theses textures are generated, in many cases, taking a snapshot of the modeled façade, painting the materials directly on it, with a digital painting software, using bitmaps from photographs of similar buildings and projecting back these bitmaps on the façade.

This also means that, from the point of view of geometrical modelling, our data area extremely simple: boolean operations, extruded surfaces, parametric objects and the like, are tools that we use during the construction phase if we really need them. But once the model is finished, we save the construction file with another name, to be able to edit these operations in the future if some correction is to be made, and we convert the whole model to polygonal faces. In fact, since these operations generate triangular faces through automatic algorithms and since this usually produces long triangles that do not render very well, and that the number of faces is unnecessarily big, we try to avoid the use of these tools and prefer, instead, to model directly with polygonal faces well adapted to the model. Well adapted means: that their number is minimum, that their shape and distribution are regular, that there are not "ts", that is, vertices that finish against a crossing edge.

The organization is further constrained by hardware considerations. We avoid the use of single objects with too many or too long faces to facilitate the perfomance of graphic cards at the time of rendering.

These are technical consideration that, at last, preclude the use of current organizations in a coherent way. Initially, our models were organized in several levels that went from the lower to the higher type of entities. That is, something like: Level 1: faces; Level 2: objects; Level 3: groups or layers (or both); Level 4: archives

Level 5: the whole model integrating different archives. In parallel with this we have bitmaps, cameras and lights that may be considered as extended nodes that are connected in different ways to the general hierarchy of levels.

The diversity of levels and associated archives implies a consistent nomenclature system (except for level 1). There are interesting remarks to be made about this that we must, again, set aside for reasons of space as the naming conventions were rather complex and cannot be easily summarised.

However, as we said, there were other consideration that got into the way after the first big model we produced and that were introduced in the next ones. To achieve an efficient management of the whole model we had to reorganize everything in such a way that regular collections of similar data could be taken out of memory according to the visual position they would have in a particular visualization path. So, the model, that was initially conceived as a hierarchical and heterogeneous model, based on singular buildings, tended to become an homogeneous model, getting closer to the first type of models we have been talking about. On the other hand, as these latest models were intended to be interactively navigated, they had to be organized with groups of different density that could be incorporated into a multiresolution system while they had to be subdived in several view dependent chunks. This meant, among other things, that grouping geometry into single buildings was usless, as façades that were to remain hidden should not be loaded in a particular camera path. And façades that were to remain at a particular distance could be grouped in a simple object. This reorganization may be done semiauthomatically as there are algorithms that may be implemented in the model (there are many LOD simplification algorithms). But we consider that it takes longer to implement these algorithms than to do it by hand. And this is not as trivial an statement as it may seem.

Therefore the model had to be, at the same time, very precise and very light. Very precise, in order to represent with high accuracy the subtle details of most of the buildings which incorporate complex geometry and rich texture (about 2 Gb and 1.5 million faces in the last case). And very light, in order to accomplish the second requirement: to be navigated interactively, in a current platform, by different kind of people including those who are not very familiar with computers (about 300 mb and 300.000 faces maximum). These two requirements could not be accomplished at the same time but have to be tightly related. On the other hand, although universality was an important issue, as the model had to be shared by different platforms, we discarded current navigators and vrml, as the restrictions implied upon the quality of the result would be too high.

Conclusions

The question is how should a pure visual model be organized. Our method is a combination of homogeneous and heterogeneous subdivision that is directed by hardware considerations but that it is at the same time closely related with scale considerations and final objectives and intentions. These methods are based upon the experience of having to deal with quite a few big models. We believe that no development of more complex data organization (i.e. 3D GIS) can be reached at, whitout a deeper analysis of the technical problemas we have indicated.

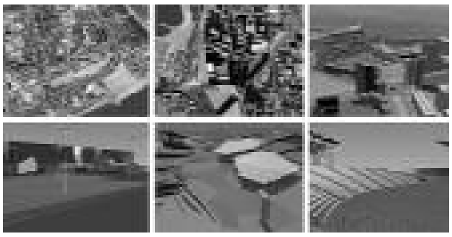

Figure 3. Examples from the model of the Forum 2004 at Barcelona. The first image shows the DTM and projected bitmap, the second is a mixture of DTM and projeted bitmaps and extruded blocks, the rest are images from the detailed model (40_ monedero_munoz_fig03).

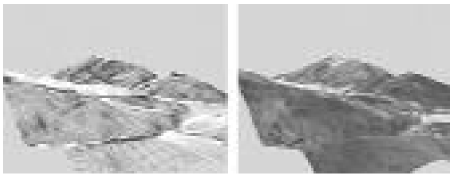

Figure 1. A project for Navarra (Spain). DTM and projected bit map (40_ monedero_munoz_fig01).

Figure 2. Examples from the model of the city of Cadiz at the XVIIIth centtury (40_ monedero_munoz_fig02).

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