

3D City Model of the Ancient Hue, Vietnam; Reconstruction of the City Environment for the Cultural Heritage Identity Conservation

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Abstract. To have a correct knowledge and codification of their historic-cultural heritage, various Asiatic countries today present common problems. In particular the most urgent need is that of analyzing the heritage in order to be able to protect it and show it to better advantage without coming into conflict with the social transformations that are taking place in those countries. For this reason Virtual Reality is an instrument able to support this process. In the presented project the Italo-Vietnamese researching group has elaborated a 3D City Model of Hue, Vietnam. The object of this study is therefore an entire city that, in consideration of its existent cultural possessions, needed to undergo an all-over reconstruction in order to recreate a complete 3D environment. There are numerous possible applications from the model: Multimedia products, videos, render, together with a return of future projections of the city's development and monitoring of the urban evolution.

Keywords: Virtual environment, Cultural heritage defence.

1 Introduction

The paper describes the stages of the realization of the 3D Virtual Model of the ancient city of Hue in Vietnam, carried out by the united Italo-Vietnamese staff. The city of Hue is characterized by the presence of an immense cultural heritage still very little known at an international level. Vietnam, the country into which the research has been inserted, appears to the researchers' eyes as a country with new stimuli compared to the well-known European environments. In fact everybody knows that such a process of high economic growth and of social transformation, which is at present taking place in this country as in other Asian countries, may cause a rapid loss of the cultural roots of the population together with a loss of identity, especially among the new generations. In face of these types of problems common to the Last Developing Countries, Virtual Reality can play a fundamental role not only in reconstructing the image of the ancient environment and in witnessing it in the future, but also in supporting the choices of urban development that are at present taking

place. Starting from these general aims, research has verified that the documentary material of Hue's cultural heritage was already present and plentiful, even if it is mainly made up of orthogonal projections. This material, still very precise, has not however the power of being visible, interactive and easily accessible for the local and also foreign users who want to learn more about this city. Therefore research has created a Virtual Model of the city of Hue, fusing in a unique virtual environment three components: the landscape, the historic architecture and the residual urban texture.

In fact, as we shall see, the city of Hue is a Monumental City deeply harmonized with the natural ambient and the popular building industry, so a serious Visual Communication of this city must mould together the three elements in a unique representation.

2 Method and Stage of Work

The Virtual Model that has been carried out had the following aims:

- to reconstruct the all over image of the city of Hue, through the virtual reconstruction both of the areas still preserved or however existent, and of the areas destroyed by the bombing during the war against the United States
- to communicate in a simple and interactive way the quality of the cultural heritage of the city of Hue using a unique model of the city composed of 3d models of the monuments with a discreet detail level
- to create a virtual environment in which to experiment the planning solutions on both an urban and building scale
- to monitor the development of the city foreseen for the following twenty years both in terms of building expansion and in terms of safeguarding of the presence and recognition of the monumental system.

First Stage. The first step has been represented by the creation of the territory and of the water landscape that strongly characterizes the city. For this reason the method of virtual reconstruction was based on high resolution satellite imagery but also on elaborate autocad vectorial maps. This material has allowed us to re-create the territory, the waterways (rivers) and the slight mountainous reliefs that surround the city. The elaboration process was principally based on the use of the popular software AUTOCAD also chosen to be globally known and therefore to facilitate the long-distance work between the Italian staff and the Vietnamese staff. Secondly the work of the mapping of the land was carried out with the 3d STUDIO MAX software which allowed a precise placing of the high-resolution satellite imagery on the reconstructed portions of the territory. In this stage, it was plain that in spite of the good quality of the satellite imagery, it didn't have a clear definition such as to sustain a visualization of a virtual environment according to the scale of the building. Therefore the development of the model in a future stage foresees the insertion of digital photography areas carried out in portions.



Fig. 1. Satellitar view of the ancient Hue Citadel, Vietnam. It's possible to see the main walls, the canals and the Huogn River.

Second Stage. The second stage of the work concerned the creation of three-dimensional models of the monumental complexes of the city. The existent material was very heterogeneous and different methods were used to carry out the 3d models. The problem common to all the methods was to create the most agile models possible in terms of file dimensions since, at the moment of the joining up of the city model, there would result problems of the management of a very heavy model even for specially sophisticated machines such as those used by the two staffs. Therefore a compromise was reached among the detail levels of the 3d models, establishing some minimum standards relative to the dimensional reliability of the models, but the levels of detail were not carried out beyond a certain limit.

Generally speaking two methods of representation were used according to the presence of 2d reliable reliefs:

- 2d reliable relief: creation of a 3d model through software Autocad and mapping through 3D STUDIO MAX
- 2d non-reliable or inexistent relief: creation of points cloud through digital photographs (speditive photogrammetry) point elaboration through software PHOTOMODELER and mapping through software 3D STUDIO MAX.

The first method was used for the monuments that presented some reliefs, available thanks to the local institutions and found by the Vietnamese staff. In particular:

- four of the ten entrance doors of the ancient city (Sap Gate, etc)
- some portions of the town-wall of the historic city
- the Pale Blue Pagoda and the Literature Temple.

The second method has instead been used for the other monuments. In this sense the system of speditive photogrammetry has proved itself specially useful as it is based on some certain measures and on digital photographs taken in the appropriate way.

The photographic survey, using the techniques described above, was performed according to the following sequence:

- Photographic survey of the monuments and photograph cataloguing
- Identification of viewpoints on the photographs

- Image rendering using PhotoModeler software (generation of points cloud by the extracting of homologous points)
- Points cloud processing – generation of the wireframe model
- Creation of surfaces for the textures
- Scale definition by entering a known measurement.

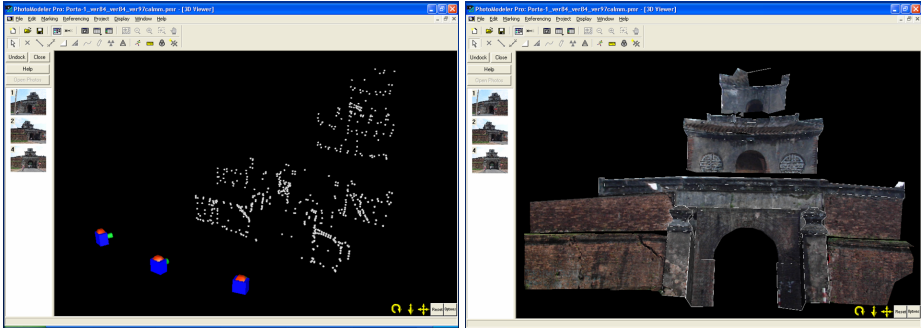


Fig. 2. Elaborations and mapping of surfaces. Clouds of points obtained from processing of digital images of monuments.

These methods of survey have proved to be particularly well suited for architectural heritage protection programmes, as detailed photographic surveys of monuments, encompassing all their portions, are sufficient for a faithful rendering. Overall, collecting sufficient information on a large number of buildings requires a few weeks for the on site work; processing can then be performed at a remote and shared online.

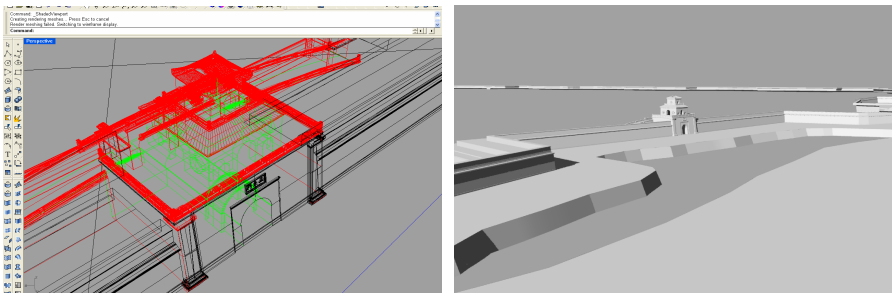


Fig. 3. Modelling of citadel rampards, walls and gates and modelling of landscape and transportation ways.

Third stage. In the third and last stage of the work the models, performed also by distinct persons who participated in the research project, have been assembled in order to extrapolate a total image of the city. This job has been carried out through the 3D STUDIO MAX software from which then, render, animations and films have been extrapolated for the representation and divulgation of the pre-war image of the city, in

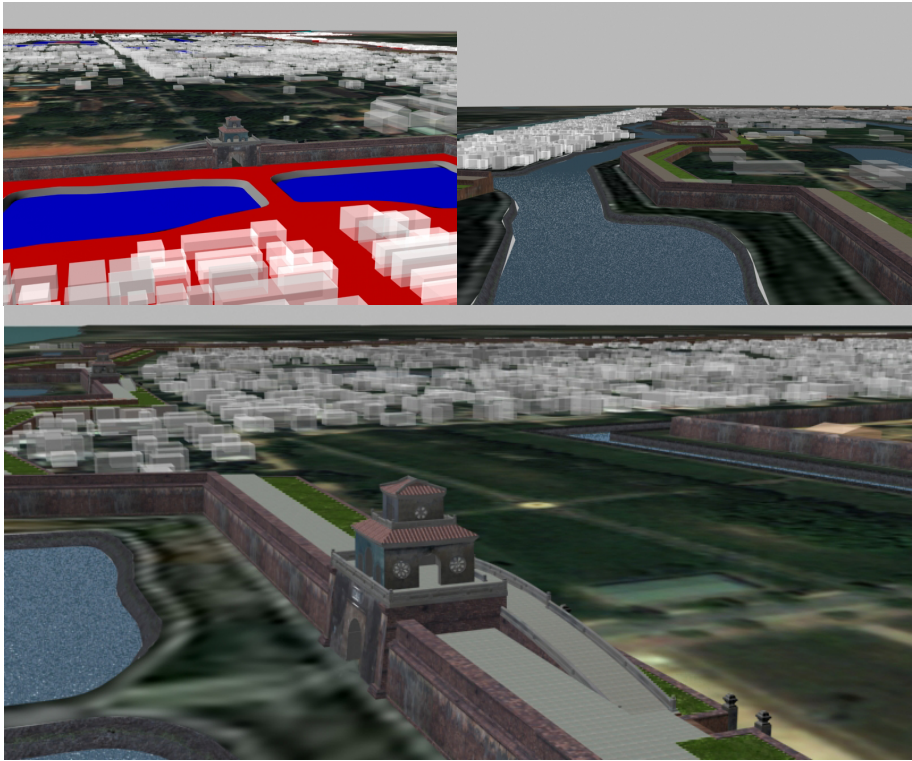


Fig. 4. Mapping of citadel walls and gates. Mapping of earth trough elaboration of satellitar images.

which all the destroyed elements have been reconstructed in the Virtual Environment. Running parallel a Virtual Model of the City of Hue, that shows the state of present preservation of its monumental possessions has been created. In this stage the work of the mapping of the monuments, carried out thanks to a vast and complete photographic survey of all the city's monuments adjourned up to November 2005, has been especially important. The mapping of the 3D models through images, has been possible thanks to a work of photo-straightening of the same images by using TriDimetrix software. This software permitted the re-elaboration of the images eliminating the distortions caused by the instrument and the straightening and scaling of them thanks to the knowledge of a well-known measure and of some alignments.

The 3D City Model has been completed by the creation of a background of urban building, obtained through some elaborations of the available vectorial maps.

The detail level of the 3D City Model has therefore been tared according to the urban scale both for problems of the elaborating capacity of the available computers (that is often still more restrictive if carried out in the Last Developing Countries) and for the immense quantity of data to be elaborated. Also for this reason, we haven't gone, at least up to this moment, so far as introducing in the Visual Models elements of the completion of the virtual ambient such as the sound-effects typical of the city,

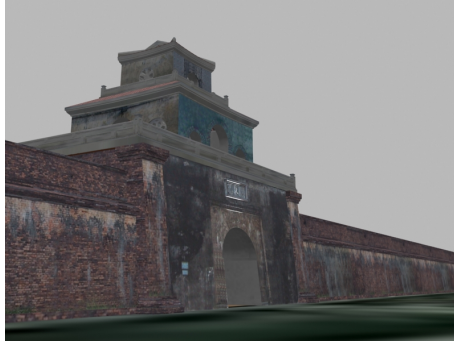


Fig. 5. 3D reconstruction of Sap Gate. The Gate has been mapped with texture obtained from elaboration of digital images.

the vegetation and lighting effects. However we must underline how the attained compromise has managed to satisfy the requirements we had initially aimed at. In particular the creation of the virtual city has allowed us to carry out Virtual simulations of project interventions concerning both the introduction of new building objects or the restoration of the existing ones, and plans of urban development.

3 The 3D City Model of Ancient Hue

The City of Hue presents one of the most significant examples of an eastern citadel in entire South-East Asia. The dimensions of the main town-wall, that enclosed the historic city, the imperial city and the forbidden city are already in themselves a significant datum: a square with a side of about 2,3 km and a perimeter, shaped by 24 ramparts, to be crossed passing through ten doors. The internal surface is of about 500 hectares subdivided into nine distinct areas by four main route axes.

The construction process of the citadel of Hue coincided with a historical period characterized by profound changes and innovations of the local culture due especially to the presence of French colonies, during the dynasties of Gia Long and Ming Mang (1802 – 1840). The city planting is based on the generating principles of Vietnamese tradition, in which the first kinds of fortified cities date back to 250 b. C. with the construction of the citadel of Co Loa near Hanoi. However the Vietnamese citadels had an identity of their own, made up of subsequent concentric town-walls, where the external ones adjusted themselves to the land with oval or circular forms, while the internal one, that enclosed the Emperor's palaces, was constituted by a rectangular plant. The massive walls were made up of compact earth covered with bricks or baked clay and might be even 25 meters thick.

Therefore the 3D City Model has, as a fundamental element, the town-wall system, which has been reconstructed thanks to the representation methods already illustrated above. The town-wall system is made up not only of the town-walls but also of the double order of artificial canals that surround them, which have also been represented. The rather accurate representation of the town-wall system has been fundamental since the city lives its equilibrium of development between what is “internal” to the

citadel and is always changing and what is “external” that tends to grow and to dispel the dominant role of the ancient city.

The system of the Access Doors is also associated to the system of the town-walls: The Access Doors are set at each side of the quadrilateral and are 11 altogether, two for each normal side and five for the main side, the one against which the forbidden city leans, that according to eastern tradition is turned towards the South-East (or the South). The doors were, originally, all identical, except for the central door of the main side, the Ngo Mon Gate, which unconditionally represents the passage between the “external” world to the city and the “internal” one. During the period of the American bombing many doors underwent some substantial alterations. Some, such as the Nha Do Gate or the Huu Gate were completely destroyed and some of them have today been reconstructed. Others such as the Dong Ba Gate were altered to achieve shooting points in reinforced concrete which substituted the original turrets. Thanks to the model, there also appears clearly the collocation that the city and the monumental sites assume, as to the orography of the land and as to the water system.

The choice of the site in which to set the city and its orientation, which would dictate the orientation of the streets and both the real and popular residential buildings, was based on Feng-Shui and “Dich Ly” rules. Differently from the fortified Chinese cities orientated along the North-South axis (Beijing, Xi’ An), the Citadel of Hue is set along a North-West South-East axis. The reasons that have led the “geomancers” (the preservers of Feng-Shui culture) to distinguish themselves with regard to the Chinese tradition are bound to the same physiognomy of the place. In fact Feng Shui and Dich Li indicate the screen, the water, the open surrounding space, the blue dragon and the white tiger as favourable elements in relationship with the building. To favour the simultaneous effectiveness of these elements the builders have therefore rotated the usual axis up to the direction that best allows the integrating of the water system represented by the river Huong, the isle on the left and the one on the right as the white tiger and the blue dragon respectively, Mount Ngu Binh with a screening function on the city. Nature itself has therefore defined the urban system of Hue. The 3D City Model shows these peculiar aspects of the city of Hue, suggesting general views, guided visits, cultural virtual routes of the city. The simplified reconstruction of the internal quarters and of those immediately external to the town-wall, permit one to perceive the evolution of the dwelling density that is being attained.

A significant experience of the employment of the 3d CITY Model in the field of control and monitoring of the architectonic and urban development has been carried out by inserting the project of four important poles for services which the united researching staff has planned in order to restore some crucial areas within the historic city to their recognizability. In fact the projects were to be inserted in correspondence with the four main axes that subdivide the surface of the citadel in nine blocks. In the builders’ original design these points had to represent the passage points among internal areas associated to different meanings and to be clearly identifiable by whoever went through the city so as to maintain a precise orientation. Subsequently, owing to the intensifying speculative building presence, these points have lost their degree of both functional and symbolic recognizability. Therefore four projects of urban increase in value of these areas have been elaborated, and controlled through

continuous simulations and tests within the 3D City Model. This process has systematically harmonized the force relationship between empty and full spaces, masses and surfaces, in order to integrate the intervention to the existent architectonic urban system without creating discontinuity in the present urban system.

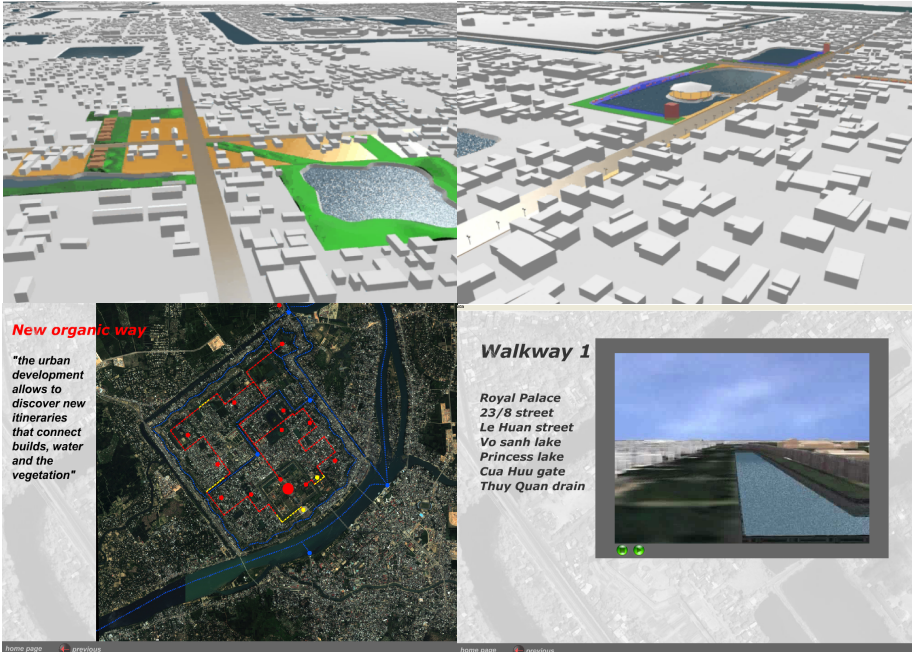


Fig. 6. Simulation of environmental impact of architectural plan inside the Citadel. Proposal of urban planning of the monumental areas.

Another useful experience for testing the functionality of the 3D City Model was the one regarding the re-planning of the Mang Ca quarter set in the North-East quadrant of the citadel. In fact, along the internal tract of the road that connects the Trai Gate to the Chan Tay Gate, a quarter with a mixed residential-commercial destination is going to be reconstructed in the free area, presently occupied by the Army. Consequently the 3d model of the new quarter project has been inserted in the Virtual Environment.

These two experiences have therefore shown how the use of the 3D City Model for controlling and verifying the new projects or interventions of restoration is useful on two levels. For the active persons of the planning process, that is to say for managers, investors and architects to be helped in administering the transformations to integrate them with the present urban system. For the passive persons, that is to say the citizens who have the possibility of participating in the urban transformations with simple and effective communication instruments at their disposal such as multimedia products, films, render.

4 Multidisciplinary Contributions and Collaborations

In the work of realization of the 3D City Model of the city of Hue several competences have joined.

The international cooperation between Italy and Vietnam has consented the gathering together of different approaches to the reconstructing work.

In detail the work has been carried out by:

- Italian and Vietnamese architects, researchers and professional men who have performed the work of researching historical documents, the controlling operations of the mapping phase of the virtual model, software employees: Autocad 2004, Rinoceros, 3D STUDIO MAX 6.
- Designers and graphic computer experts who have accomplished the work of the creation of the 3D objects and also the elaboration and the retouching of the digital photographs to be applied on to the surfaces of the 3D objects. Software employees: Adobe Photoshop 6.0, Adobe Premiere, Photomodeler, TridiMetrix.
- Local Directors, Superintendents for the preservation of the heritage, who have put at everyone's disposal the bibliographic and cartographic material they had, about the monuments, and have verified the capacities of the 3D City Model of Hue in order to experiment the future urban developments.
- Designers have worked out of the 3D city Model, some multimedia products for the cultural and tourist promotion of the territory but also to present the new local urban plans of development and the transformation strategies of the 2000-2020 city. The Software used is Macromedia Flash.

5 Results

The 3D City Model of Hue, fairly precise, complete, in the initial stage of the models, of about 60% of the whole cultural heritage. Today the model being adjournable and modifiable, it has been adjourned so as to reach 73% of the represented heritage. Therefore there exists the possibility of definitely completing the work of modelling of the monuments within the next few years and of starting, for each of them, a process of adjournment of their degradation and preservation state. Nowadays the model is used as a data bank of the city's cultural heritage:

- The already experimented possibility of extrapolating, from the 3D city Model of Hue, several multimedia promotion products, such as for example, the Multimedia DVD "Hue Citadel Tomorrow", in which the city, its history and its monuments are presented, together with the plans and future development hypothesis, giving the user the possibility of viewing films of simulated insertion of the new projects and quarters.
- The Virtual laboratory for Hue's transformation, made up of the Italo-Vietnamese research group, is a fundamental instrument for controlling the extremely fast urban transformations and for monitoring the consequences on the environment, on the water system and on the cultural heritage.

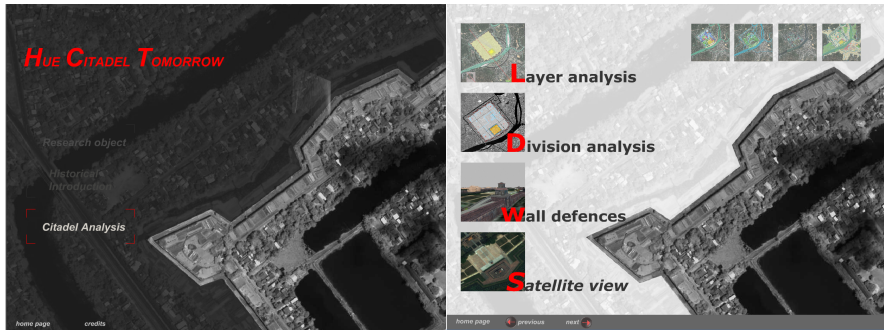


Fig. 7. Examples of multimedial products obtained from the 3D model, finalized to promote the Hue cultural heritage

6 Possibility of Future Development

Possibility of a future greater precision and insertion of a higher detail level on the monuments, sound effects of the environment, human activities and vegetation. This development is presently being carried out and is through time facilitated by the continuous adjourning of the modelling software and by the improving of informatics services. Development of a complete model to be publicly visited through internet with “Live” modalities for promoting the architectonic qualities of the city at a “global” target. Development of a website dedicated to professionals (architects, engineers, planners, etc.) where they can easily verify the impact of their project by inserting it into 3D City Model. Adapting and simplifying the model to share it on exploration software (Google Earth, visual Earth). Creation of a database of Vietnamese Architecture shared by the researching organizations and the local organizations that operate in the territory.

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