3D MULTIRESOLUTION REPRESENTATIONS IN ARCHAEOLOGICAL SITES

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ABSTRACT

Acquisition, management and processing survey data in a digital form opens up exciting new opportunities to represent the territory, its architecture, and its objects efficiently by building 3D models. In the case of archaeological sites, data and information of structures on the territory and related objects, represented in territorial scale, must be managed, processed and represented in an integrated way since they all together constitute a complex unit that can be difficult to break down. The ability to manage data in a comprehensive way emerges from the possibility to create multi-resolution models, namely, models that can be used on several nominal scales of representation. The various scales generally arise from survey at several different nominal scales of objects that traditionally need a different detailed definition, such as an entire archaeological site or a monument on the site or fragments of architecture. If these territorial objects (the site, architectures, and specific objects) cohabit within complex models which have to be managed and consequently uniformly represented on diverse scales, we have to identify strategies for survey as well as integration, with a view to achieving multi-resolution. For this purpose, it has become essential to study the relationship between the accuracy of the model, arising from the uncertainty of the measures, and simplification of the model, arising from the need to select and transmit only the geometric information deemed essential to describe the object at a given scale. Therefore, it is necessary to identify uniform criteria for the change in scale while concurrently, it is necessary to place restrictions on this scale change (or at least warnings that indicate what the range of scale is for which the model is constructed). This paper illustrates how to identify guidelines for survey, whose objective is to realize multi-resolution models of archaeological sites, in which it is possible to switch from representation of the entire site to representation of individual monuments to representation of details and other objects.

1. INTRODUCTION

The recent ministerial grant obtained for participation in the national PRIN04 research provides an opportunity to tackle themes related to the use of new technologies in the field of survey and management and use of digital data through forms of representation that are increasingly penetrating the field of survey and computer graphics and information technology. In creating a general picture of the state of the art in the sector of technologies for cultural heritage, necessary to correctly confront the research project, we notice how the boundary between the disciplines of survey, representation and information technology is increasingly permeable, where not wholly confounded, in favour of increasing integration of multidisciplinary processing systems.
The vast experience of the research bodies that testify to application of multimedia technologies to cultural heritage, with the purpose of identifying techniques and methods in the field of conservation and increasing the value of the artistic and historic legacy.
In our enthusiasm to apply increasingly advanced methods of handling and processing data, we cannot lose sight of the purposes of a survey and the principles on which our discipline is founded.

2. ARCHAEOLOGICAL SURVEY

Survey of archaeological sites is another opportunity for experimenting on the more recent instruments in the field of documentation of the form and the colour and study of the forms of representation alternative or complementary to traditional forms.
Archaeological survey differs from any other type of survey for two important reasons. The first involves the material: the variety of objects considered, from an entire building to a layer, an area of fragments scattered on the surface of the land, or ruins. As a result, it is important to understand the characteristics of the objects and understand how to use the techniques in diverse contexts, bending it to express their meaning, orienting it to document the data necessary for the study. The second reason is conceptual: the archaeological drawing is first and foremost a scientific document and as such, reproduces reality through a graphic interpretation according to fixed rules and criteria. We need to apply a method that has very explicit rules and regulations. Applying a method means that the researcher choose the most appropriate assortment of documentary evidence, chooses the graphic representational code and naturally, uses the most appropriate technique. The purpose is to make it possible to compare the evidence through double checking between documentation and historic interpretation.
The need for documentation, together with the possibility of computer management of the infographic models seems to be shifting the discipline towards a co-existence of the traditional static representations and the dynamic models. At the present state of the art, innovative approaches in survey to use and set up an appropriate cognitive apparatus include the integrated use of the more modern tools of survey such as 3D laser scanner, digital photogrammetry and GPS, in order to obtain a computerized 3D model.
Considering the complexity and breadth of archaeological sites, we are confronted with the need to survey the position of buildings in an urban area in addition to each individual building (survey of emerging architectonic objects) and every fragment that is found on the site (survey of the details). In addition to the use of survey as a study of the city and the architecture, we need to use survey as a multi-scale "receptacle" for categorizing the projections, in its instrumental use in archaeological disciplines.

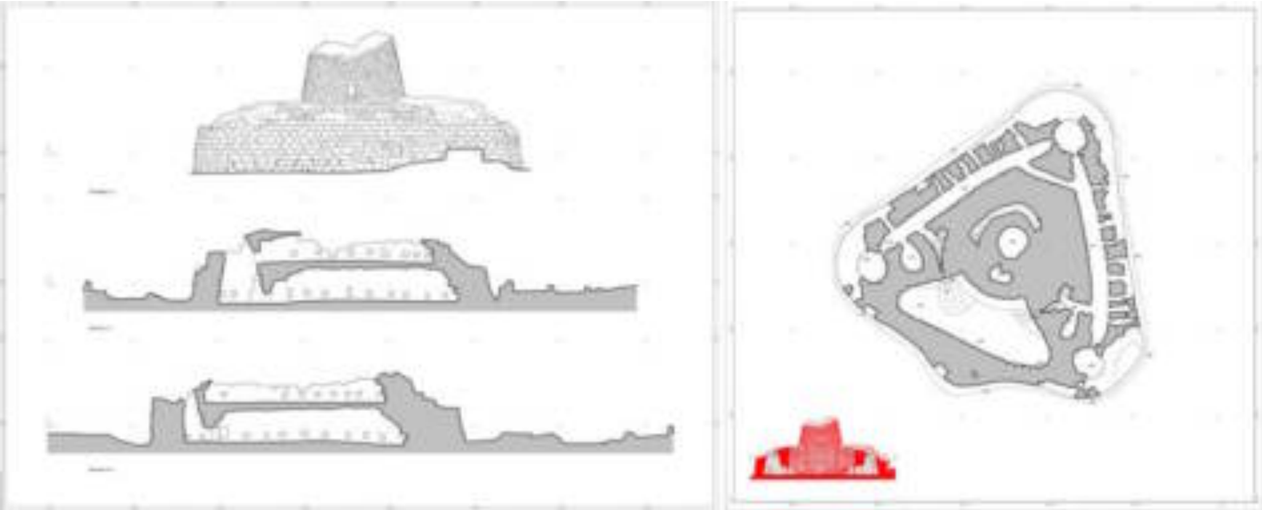

Figure 1. The survey of Nuraghe Santu Antine (Sassari)

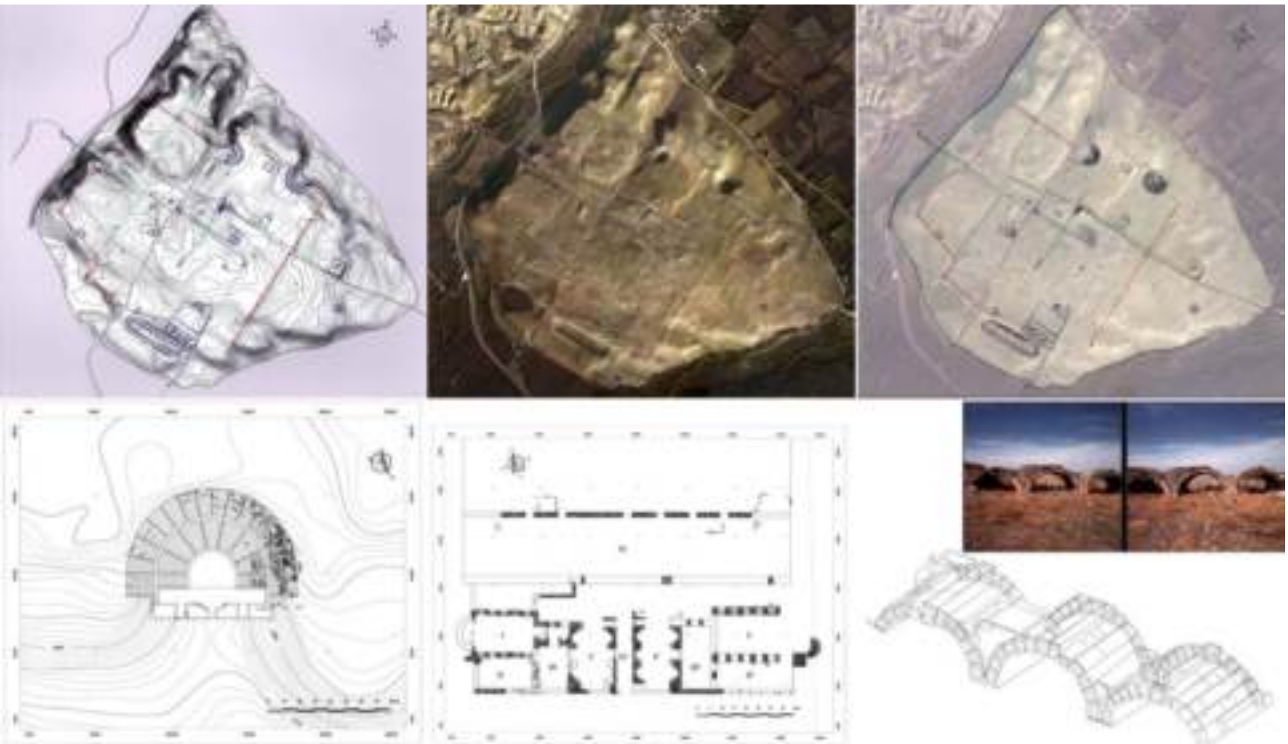

Figure 2. The multiscale survey of the archeological site of Laodicea in Turkey

The technical and conceptual difficulties encountered in our previous experiences (archaeological survey campaigns in Turkey, Laodicea 1995-2002; Greece, Poliockni 1997; Italy, Santu Antine 1997-2003), in carrying out the procedures and the diverse cultural backgrounds of architects and archaeologists have led us to reflect on the methods, procedures and instruments used in architectonic survey work in its application to archaeological sites.
At the present state of the art, innovative approaches in survey to use and set up an appropriate cognitive apparatus include an integrated use of the more modern tools of survey, such as 3D laser scanner, digital photogrammetry and GPS, in order to obtain a numeric 3D model.
Laser-scanners based on TOF distancemeters or triangulation for objects of smaller dimensions have proven quite effective in scanning 3D data (point clouds) of structures of any complexity, considering their capacity and the precision they ensure.
The method used to approach 3D scanning varies depending on the cases: the purposes of the model that needs to be scanned must always be clear. In the case of survey for geometric verification, it is indispensable to find a detailed metric correspondence between the physical object and numeric model. Such comprehensive accuracy is achieved from the type of instrument used as well as the quantity of overlapping the scanned surfaces. In recording the scanned information, the photogrammetric method of spatial triangulation has proved to be the most reliable technique to support alignment.
Point clouds must also be geo-referenced in a single reference system defined topographically in a comparable way to photogrammetrical survey. Point clouds geo-referenced in this

way represent a unique set of points which can be used to obtain the traditional representations in orthogonal projection for surfaces and, after appropriate processing, solid models.

During post-processing we can achieve documents such as: 3D volumes and surfaces, mathematical models of the terrain (DTM), processing curved planimetries of level, profile extraction, cross-section, 3D views, axonometric projections, elevations, rendering, etc.

By using various operating methods, photogrammetry can obtain a large amount of the information described above since a stereoscopic model (or a pair after respective orientation) can be assimilated to a point cloud, with the advantage that radiometric information, or colour of the points surveyed, can be added to the geometric information. This result is very useful in describing objects and the phenomena on which they must be identified.

Incorporation of laser-scanning and photogrammetry is the most advanced survey method used today and ensures the speed and accuracy of the results, while taking advantage of the speed of scanning of the laser scanner and the descriptive qualities of photographic images.

GPS enter the survey project as instrumentation that make it possible to define the position of the metric data acquired inside a uniform reference system on the entire land surface, based on satellite observations. This instrument is used to insert the survey of several objects in a local reference system into a global reference system such as the national cartographic system (Gauss-Boaga) or a supranational system (UTM).

These instruments and their techniques are added to and integrated with traditional methods and instruments (total station and levels) to realize local framing, detail and support networks absolutely necessary for laser scanning and photogrammetric surveys.

In archaeological survey, we lose all of our points of reference: there is no architecture, only fragments of architecture, in the best cases of ruins.

In survey of plane and relief areas reduced to ruins, it is difficult to find certain references (horizontality, verticality, symmetry, parallelism) to use as guides in the production of a survey.

Frequently, the surveyor can hardly even imagine a representation in relief of the ruins that are being observed.

Therefore, it can be difficult to approach and organize the survey. An unsuitable decision in the method of representation and the plan of projection can endanger the understanding of the object.

Even the choice of the symbols that represent architecture is misleading: the objectives of the architect and the archaeologist can be different depending on their cultural backgrounds, training, methods and scope of the research. For example, categories by type are predominant in archaeology and lead the scientist to seek and identify similarities rather than differences.

New instruments are necessary for representing the metric data gathered, use of more objective methods that enable the final user to carry out the interpretational synthesis.

Rectification of the survey data, due to the characteristics of the object, must use several methods of representation. Faced with the complex development of archaeological sites, while essential components are orthogonal projections through line drawings, augmented in recent years by ortho-rectified images inserted into the design, 3D elaborations have become the body of the design. Today, these can be done by processing 3D figures.

3. 3D MODELS FOR ARCHAEOLOGY

The research project proposes to explore the possibilities of survey and representation, incorporating laser-scanning and photogrammetry techniques into the area of overlapping the disciplines of architecture and archaeology.

Frequently, some areas and monuments in these sites are studied by both architects and archaeologists, although with different methods and purposes.

The new digital technologies both rationalise and streamline the survey procedures while also creating the new infographic representations that can easily adapt to the multiple needs of the scholars and operators (architects, archaeologists, engineers, restorers, historians).

Of these representations, 3D models with mapped surfaces are surely the most versatile. The mappings can be simple integrations of the geometric model, in the case of photorealistic textures or the result of specific analyses.

The 3D models for representation of an archaeological area, with its architectonic emergences, play the role of recording the actual conditions (geometric model) and to provide support to analysis that the professionals can realize.

Of particular interest from a technical perspective are the survey procedures accomplished by incorporating laser-scanning and photogrammetry in the case ground level or underground portions of archaeological sites. The paper demonstrates the positive aspects of realizing a digital model of the site using a DEM, whose data are surveyed from the ground with a laser-scanner and calibrated aerial views, taken by a tethered balloon or other means of elevation.

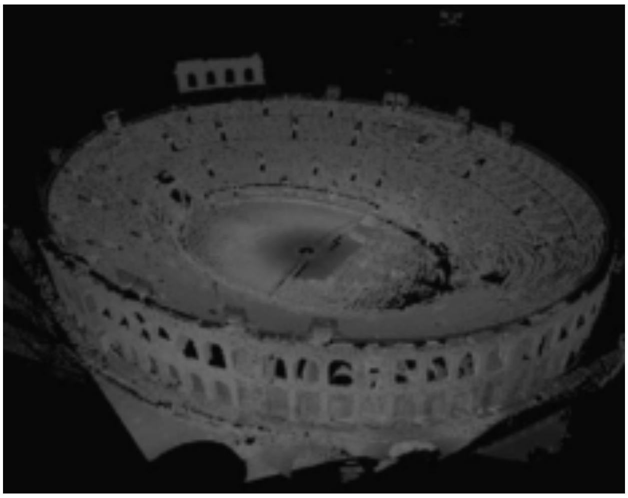

Figure 3. Laser scanner survey of a part of Arena

4. MULTIRESOLUTION

The opportunity offered by geometric 3D models that warrants extensive further investigation is the possibility to realise multiscale models, namely, models that can be used on various nominal scales of representation. The range of scale generally derives from the survey of objects at different nominal scales that traditionally need very different detail definitions such as the entire archaeological site (scale 1:2000, 1:1000, 1:500), an individual monument on the site (scale 1:200, 1:100, 1:50, 1:20), or smaller objects such as statues or fragments of architecture (scale 1:10, 1:5, 1:1).

If these territorial objects (site, architectures, individual objects) must cohabit within complex models which have to be managed and consequently represented singularly on diverse scales, we have to identify strategies for survey and integration, with a view to achieving multi-resolution.

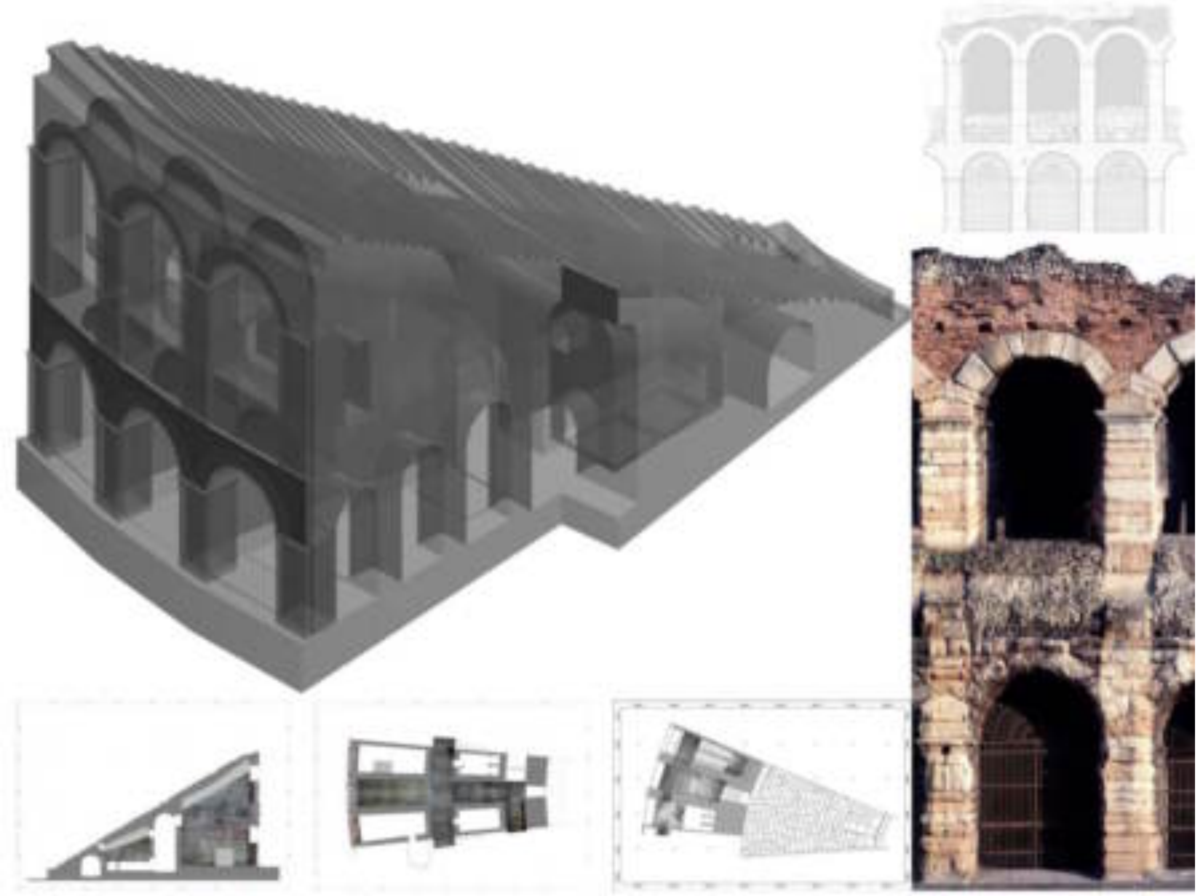

Figure 4. The 3D solid model of a part of Arena of Verona

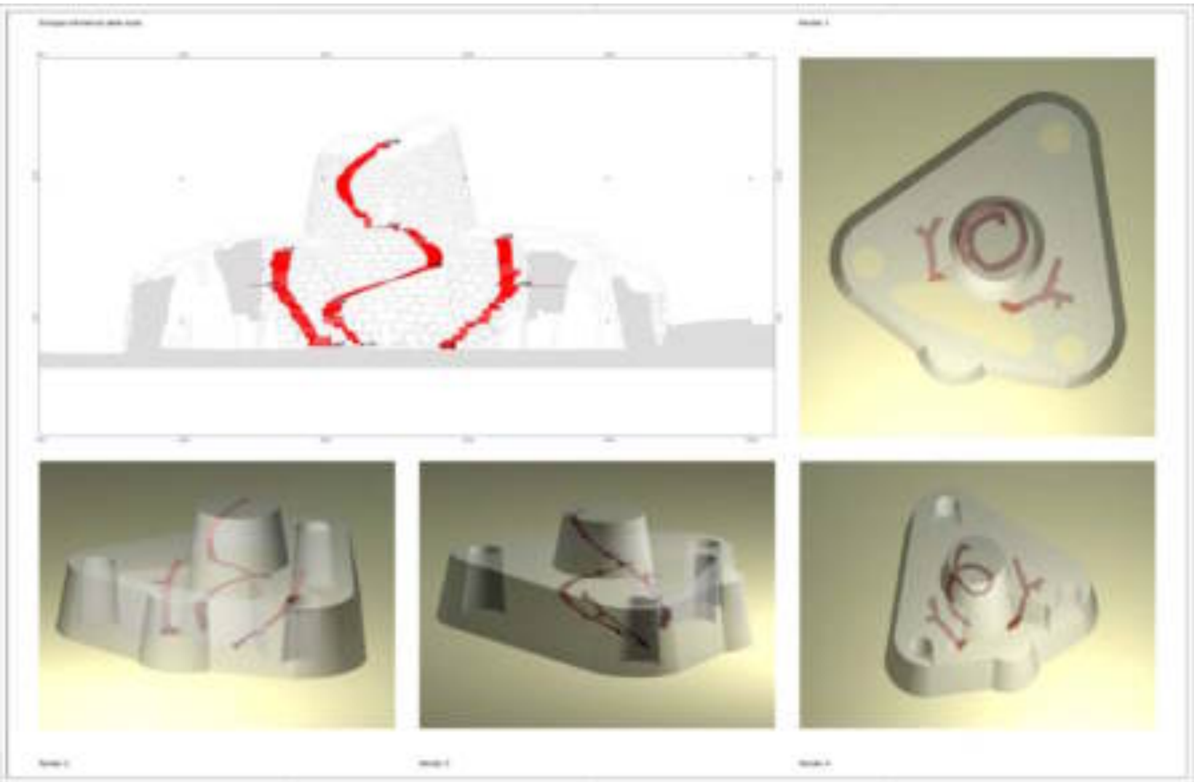

Figure 5. A simplify model to underline the stairs development of Nuraghe Santu Antine

Representation of geometric forms is naturally applied in the field of cultural heritage, as a support to the knowledge and use of the information by the user, expert and non-expert in the sector. Unlike the classic Monge projections, geometric models are 3D reconstructions of the form of the objects which can generate arbitrary views. A typical use of these models is in virtual reality systems, where the user can move freely around the object or inside it (in the case of large areas). In addition, it is possible to represent not only the actual form of the object, but also the assumption regarding its original form and the place where it was located, a fundamental application in the sector of archaeology.

Geometric representation is also applied in the handling and digital representation of data obtained after analyzing the objects. Dissimilar data in numeric and geo-referenced format can be considered mathematical in the same way as a function that associates a value to each known point P=(x,y,z) in a 3D domain providing assistance to the comprehension and analysis of the data prevalently oriented toward expert users such as archaeologists and restorers.

The techniques available today make it possible to take very accurate samples on an object by producing very dense or high resolution triangle grids and tetrahedrons : the higher the resolution, the better the geometric model matches the reality represented. As it is made up of many tetrahedrons, the high resolution model leads to management problems relating to the occupied memory and the processing times. As a result, it is possible to have a very accurate model, but unmanageable and impossible to explore in real time.

Geometric modelling through polygonal models obtained from laser scanner data on urban areas or parts of the territory, as well as descriptive high-resolution modelling of small objects has highlighted the problem the management and representation of the data structures used to describe the geometries. The quantity of data necessary to memorize a complex polygonal geometric structure can easily occupy all the memory of the most modern computers.

This problem can be partially resolved through a simplification that is based on a fundamental principle: consider the complexity of a high resolution polygonal structure in order for a human observer to perceive geometric details it is not necessary for this structure to always be managed and represented at the maximum level of detail available.

This assumption has led to the development of multi-resolution techniques that make it possible to check the level of detail with which a geometric structure, or its sub-parts, is representative. In computer graphics, there are techniques to simplify triangular or tetrahedral grids that make it possible to selectively reduce the resolution of a grid by thinning its density.

There are two different methods to implement these techniques:

1. The first technique is based on the real time management of a complex polygonal structure by a software and hardware system that manages the most appropriate representation, instant by instant. The disadvantage of this technique lies in the intrinsic limits that every hardware mechanism must be subjected to in terms of maximum performance and in the engineer’s ability to control the level of detail of a geometric structure and its representation.
2. Another technique consists in preparing a series of models of the same geometric structure with different complexities, depending on the different needs of representation, that will be established by the engineer of the geometric structure. The parameter discriminating the level of detail necessary to use is generally the distance between the virtual observer of the geometric structure or part of it. This technique has the disadvantage of having to realize several models of the same structure, which occupy a larger quantity of total memory; however, these models are managed in different files that are uploaded into the memory of 3D graphic representation only if actually necessary. This is the technique used by the VRML language. A multi-resolution model incorporates the alternative representations of the same geometric shape at different levels of resolution.

Application of these techniques in the field of survey should meet the needs of precision that usually characterize the documents of a survey in relation to the nominal scale of the representation.

For this purpose, it would be opportune to investigate the relationship between the accuracy of the 3D model, arising from the uncertainty of the measures, and simplification of the model, arising from the need to select and transmit only the geometric information deemed essential for description of the object at a given scale.

It is essential to identify uniform criteria for the change in scale as well as imposition of restrictions to this possibility of change in scale (or at least the warnings that indicate the range of scale for which a model was built).

The research campaign underway acts as an objective of the study of the techniques, shaped to meet the needs of survey. The theme of multi-resolution can be confronted through a study that leads to identification of invariables with respect to the scale of representation in geometry of the object, according to a review of the cartographic concept of generalization. Essential is the phase of geo-referencing that will be realized by the topographic survey and GPS of unvaried control points in several scales of representation: In geo-referencing, the focal point is maintaining the metrical characteristics of the surveys at the diverse nominal scales.

Verification of the survey procedures and individual evaluation will be made in application of these specifications to real cases. The applications will take place in the summer 2005 on two Roman era archaeological sites (Aquileia and Grumentum).

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