USE OF 3D MODELING FOR ARCHEOLOGICAL ARCHIVING IN A SENSIBLE AREA

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ABSTRACT:
Due to political and social situation which followed local riots and war, in the SW part of Balkan Peninsula, the large existent archaeological and civil treasure, mainly the Orthodox Monasteries, is heavily threatened.
So, we need collect, record and make available all information data, which appear representative of this precious heritage.
A G.I.S. system has been developed to this aim, in order to save and store elements for historical, cultural, artistic information; this task is obviously made difficult, by present political, social and ethnical situation.
At present we have new powerful methods for storage and archiving; in any case behavior of mankind has not greatly improved as long as conservation related, so the danger for heritage is greater than ever
3D topology analysis and management are very important tools for 3D GIS's, like Architectural Information Systems. On the other hand, 3D topology analysis and management can really become complex, if the processing is performed by the selection of feasible realizations among all theoretical combinations. Let recall that factorial numbers, which govern the combinatory calculation, increase strongly very quickly. On the contrary, if the base to analyze and manage the data is the cardinality given by groups of symmetry, 3D topology analysis and management can be quite easily arranged.
3D topology analysis and management is presented as a scientific software, developed with the specific aim to answer positively of the above mentioned tasks, even if the present paper is still at the level of work in progress

1. Introduction, the fore facts

Christian-orthodox monasteries in Kosovo area, have been suffered heavy damage, even destruction, from war events and general disorders, specially in the years from 1998-2004.
We deal with an important part of medieval culture, in the special area of Balkans, where Byzantine culture interferes with local interpreters of Slavonic and Greek schools, not neglecting local influence from the great western architectural and pictorial tradition, mainly trough Dalmatia.

Fig. 1 Mušutište church at present

The historical periods of Serbian artwork and art as a whole practically overlap with the basic periods of Serbian political and national history. Undoubtedly, within the temporal boundaries of Serbian history, three caesurae were decisive

Fig. 2 Mušutište church before 2004

The first occurred in the middle of the twelfth century, when the state of Raška was being built (Stefan Nemanja became the founder of the dynasty that ruled for two centuries). in the Raška style, the church has only one nave and one dome. A nartex lies on the western side; inside, some small chapels are present. Although eastern as to their origin, this style has come to Serbia via the Dalmatian coast. Indeed, both portal and windows are often enriched with sculptures and stuccos, the same as in Dalmatian churches.
From Byzantium, the monumental and plastic language of painting was accepted. The second great change occurred at the end of the thirteenth century with the expansion of Serbia into the Vardar Basin and Macedonia. The new style, the so

called Serb-Byzantine style, is proper of Kosovo and adjacent areas of Macedonia.

The basic form of the church is the Greek cross, not free, but included in perimetral walls. The dome is based on pillars, not upon side walls. Normally, the highest dome is the central one, as at Gračanica (1313-1321), or at Hilandar monastery on the Mount Athos.

The Morava School is active in an obscure age of the Serbian history, from battle of Maritsa (1372) until the definitive Turkish dominium (1459).

In the interior, the pillars sustaining the dome, are almost trapped in the walls, so that the general look of the church resembles the single –nave; facades and nartex are largely decorated, somewhat like Armenian models.

The Turks occupied or annexed large territories in the South.. At that time, the coastal Catholic areas accepted the Gothic style from the West. They influenced Orthodox believers with it, including followers of the Bosnian church as well, who were more closely tied to the towns on the Adriatic.

In the age of Stefan Nemanja, and until king Milutin, paintings generally are plastic and magniloquent: faces and bodies are elongated, the eyes are large.

Later, paintings becomes more decorative.

Fig. 3 Inside view of Mušutište church in 2004

2. A PROPOSAL

A G.I.S. system has been developed to this aim, in order to save and store elements for historical, cultural, artistical information.

Since information proved difficult to collect, and also due to cost, we used the huge potential of the web for our purposes.

In the first step we have put together the needed cartographic elements; also collected historical, social and geographical information issues and chosen 40 churches and monasteries, for their special significance, both historical and artistical.

Fig. 4 Fresco at Dečani

The said step has been cross-tested by the records of church authorities, and personal inquiries.

The aim of our work is to keep awake the interest on the theme, in view of future developments in the field.

The GIS has function of a data archive, so inside the system a web component will be considered, in order to data retrieval in view of future usage.

The opportunity to show on a computerized map the historical «net» of these religious handmade articles, whose traces are findable anyway, even though a lot of them have been destroyed and many others have been damaged in different ways, it allows us:

❑ to preserve both the memory and the environmental identity;
❑ to investigate and to acquire unpublished anthropic, historical, architectural records;
❑ to indicate any possibility of recovery;
❑ to provide a starting point for new monitoring and research activity;
❑ to consider the recovering condition, whereas it took place any previous repairs and/or reconstructions;
❑ to promote the fruition of a high historical and cultural heritage by a wide international audience (tourism of quality).

Unfortunately, once a monument is destroyed, it cannot always been rebuilt, because of the unfavorable, contingent conditions. This is why the latest archiving technologies should be always used in advance, in order to catalogue the cultural heritage and to preserve the memory in case of its destruction.

At present, some forty geo-referenced spots are available, which are linked to a database including historical-architectural information and data about a past damage, and some pictures (Fig. 6).

In order to achieve a 3D GIS, we need have more pictures, photos, surveying data, etc.

Fig. 5 Gračanica

Unfortunately, just when we miss things (often, the important ones) we notice how much we lack them (Fig. 5)

3. OBJECT MODELING

The object modeling is an innovative and technologically advanced tool for the analysis of spatial phenomena, since it allows the widest possibilities to represent bodies and figures. In fact it considerably increases the complexity of realization and management of the informative system.

The object paradigm supplies a high level of abstraction of the physical structure of the data; it is able to model the system according to the definition of the data (objects), as well as to operate on the concept of attributes and relations, being both stored as an integrating part of the same objects. The object oriented representation permits to create complex objects, like polygons, 3D bodies, etc, analyze and manipulate them like single objects (even if they are combinations of objects). This characteristic eliminates the necessity of clarifying all the geographic and semantic attributes of the objects.

Churches and monasteries have obviously a complex geometry: 3D topology analysis and management are very important tools for 3D GIS's, like Architectural Information Systems. Indeed buildings, monuments and many different bodies present three dimensions, often comparable among themselves, so that 3D treatment, description and representation are particularly relevant and significant. On the other hand, 3D topology analysis and management can really become complex, if the processing is performed by the selection of feasible realizations among all theoretical combinations: let recall that factorial numbers, which govern the combinatory calculation, increase strongly very quickly. On the contrary, if the base to analyze and manage the data is the cardinality given by groups of symmetry, 3D topology analysis and management can be quite easily arranged. For these reasons, 3D treatment, description and representation, after the selection of the obvious base elements (points, edges, faces and bodies), transform the first two into nodes and arcs of primary graphs, and the last ones into arcs and nodes of dual graphs, setting up a cross-connection table between arcs and dual-arcs, i.e. between edges and faces. 3D topology analysis and management present many different treatment, description and representation, in form of tables or charts, nodes to nodes and arcs to arcs, as well as nodes to arcs and vice versa, taking into account both primary graphs and dual graphs.

3.1 Relations among the object elements

In order to construct a formal data structure, it is necessary to identify geometrical features of objects and their relations.

As the first step, one may operate with different methods, any case, once complex objects have been someway defined, it is necessary to establish their mutual relations in the space, where they are located (in terms like*: at the right or at the left, inside or outside, over or under, intersects, etc.*).

We can notice that the topological / geometrical relations in one dimension are 7; they are however 17 in 2D environment and 32 in 3D space.

Indeed, in order to obtain a broad starting point, very general relations among complex objects are defined, as follows:

❑ 3 classes of relations in the one-dimensional space: between points, points and lines, lines;
❑ 6 classes of relations in the two-dimensional space: beyond to those of the previous case, between points and surfaces, lines and surfaces, surfaces;
❑ 10 classes of relations in the three-dimensional space: beyond to those of the previous cases, between points and 3D bodies, lines and 3D bodies, surfaces and 3D bodies, 3D bodies.

In one dimension, topological relations are 7:

❑ Point – point: separate
coincident
❑ Point – line: external
internal
❑ Line – line: separate
connected
internal.

In two dimensions, 10 new relations join to the previous ones, defined for the one-dimensional case, reaching the number of 17 topological relations:

❑ Point – surface: external
internal
❑ Line – surface: external
connected
secant
internal
enucleating
❑ Surface – surface: external
connected
internal.

Finally in three dimensions, 15 new relations join the previous ones, defined for the two dimensional case, reaching the number of 32 topological relations:

❑ Point – body: external
internal
❑ Line – body: external
connected
secant
internal
enucleating

❑ Surface – body: external
connected
secant
internal
enucleating

❑ Body – body: external
connected
internal.

The main geometrical relations among primary elements are not lesser than:

❑ 10 geometrical relations, for the one-dimensional case;
❑ 32 geometrical relations, for the two-dimensional case;
❑ 230 geometrical relations, for the three-dimensional case

Especially, in the three – dimensional case, it is quite easy to reach the number of 230 elements. In fact, while a point is a point and a body a body, a line can be open or close, and it can occupy an open area or close area, as well as a volume; moreover a surface can be open or close, and it can occupy a volume.

3.2 About symmetries

A proper language for symmetries is the group Theory: the whole of all the transformations gives place to a group. Abel and Galois, two very young people, first found group theory: they both started with the same problem (resolution of fifth grade equation) to reach the general theory of groups.
Most common examples of linear and planar symmetry are decorations, most common examples of spatial symmetry are crystals. From 1849 with Auguste Bravais, the crystallography has been one of first fields of application of group theory of symmetries. In 1890 Fedorov demonstrated that only 7 types of symmetry for liner decorations and only 17 for the planar ones exist and that only 230 types of spatial symmetry exist
The study of topological and geometrical relations among primary elements and groups of symmetries, in the spaces where the complex objects are located, shows particularly curious identities between the number of found relations and the cardinality of groups of symmetries
In fact, topological relations in one dimension are 7, as many as are the elements of the group of liner symmetries, which have one single direction of translation. The same analogy is evident in two dimensions where, in correspondence to 17 topological relations, an identical number of elements forms the group of symmetries in the plan, considering two directions of translation. Still to the 32 topological relations, characterized in three dimensions, correspond the elements of the group of symmetries in 3D space, considering three directions of translation and crystallographic restriction. Furthermore considering the main geometrical relations:

❑ 10 (number of elements in one-dimensional case) corresponds to the number of elements of the group of symmetries in plan, considering crystallographic restriction;
❑ 32 (number of elements in two-dimensional case) corresponds to the number of elements of the group of symmetries in 3D space, again considering crystallographic restriction;
❑ 230 (number of elements in three-dimensional case) corresponds to the number of elements of the group of symmetries in 3D space, without any restriction,

being 4 the number of elements of the group of liner symmetries, considering crystallographic restriction.

4. THE SOFTWARE

4.1 Input data

Simple input data are chosen for a prompt usage of info techniques in order to proper development of a 3D topology. So, a table of points, with their space coordinates, is provided with two (or three) lists:

❑ a list of areas, not belonging to solid bodies (except liquid bodies),
❑ a list, more complex, of all bodies, taken by their outer faces, which in turn are defined by their contour points,
❑ a list (optional) with all lines – open or closed – also defined by the ensemble of points: obviously, a line is open when its last point is different from the first one.

Points, lines and bodies should be numbered univocally, so that false connections be avoided (alternatively, beside any element, its coordinates need to be placed): this procedure, however, will be less robust at the end, as to possible errors for false connections

4.2 Reduction of sides and areas to arches and regions

Input data have some redundancy in information: actually, when all bodies are defined by their faces, and every face (or area, or line) is defined by its points, then some faces (and more lines) will be repeated. But, in any case, for an orderly process and development of analysis for a 3D topology, all sides should be reduced to the mere dual arches of dual graphs. For the first process, operation shall be as follows:

❑ all points of all sides are ordered on a growing sequence (according to the point codex),
❑ all sides are ordered on a growing sequence, as the sum of point codex,
❑ all double sides are eliminated.

The second reduction is more complex, as one should find out point sequences, similar each to the other, and more or less extensive. So, a possible procedure is the following:

❑ all point sequences belonging to an area (also, a face) is ordered in a growing sequence (according to the point codex);
❑ aside from the first one, all areas are accepted, only if it is different from the preceding; otherwise it is eliminated.

At the end of the said reductions, primary graphs (arches-knots), and dual graphs (dual arches, i.e. areas; dual knots i.e. bodies) are immediately available.
Notice that strictly necessary additional information is supplied by a cross-connection table between sides/edges and areas/faces.
From such information, it is easy to put in evidence 3D topologies, implicitly enclosed in input data.

4.3 Line following and region growing

The ensemble of data for analysis and management of its 3D topologies, is conventionally defined as an object.
Line following at an object requires:

❑ planning a multi-level structure, anchored at the start point of the line to be followed, and aiming at the level of terminal point of the line;
❑ back-following of any connected path, since the terminal point, with the proper choice of a specific path, when intermediate points are fixed;

This procedure puts in order a selected ensemble of segments (arches) of a line, so forming a connected path.
The procedure of *region growing* is more complex, and requires:

❑ a region (an area, a face) should be chosen without uncertainty, as the emanation spot: this is not quite trivial, for concave, no-stellar or multi-connected objects;
❑ emanated spots (areas, faces) should be selected, to be connected to the emanation spot, for transfer of the function of emanation points;
❑ more emanated spots (areas,, connected faces) should be selected, for further transfer of the function of emanation points;
❑ a proper control, so that no emanated point lies beyond possible frontiers , planar (arches) or spatial (regions), pre-existent in the object under treatment; when this happens, trespassing points are to be canceled;
❑ the last two steps are repeated, until new emanated points are found;
❑ alternately, the entire process is repeated for any other region (area, face) not yet regarded as an emanation spot, nor ever found as an emanated point;
❑ procedure stops, when all possible elements have been selected.

Finding the plane frontier of an object requires the "line following" procedure to be used, starting with contour arches. The arches belong in any case to only one face, since it is mandatory that the plane contour (which needs not be plane) be defined by areas only and no bodies (except liquid bodies). The first step to determine the spatial frontier of bodies, is assembling of all areas, using "region growing" in the proper order:

❑ planimetric contour of bodies;
❑ reconstruction of bodies;
❑ identification of the frontier in the free air;
❑ identification of the frontier on the solid ground;
❑ full contour of plane frontier;
❑ recognition of other 3D topics.

All those steps are pursued by the procedure of "region growing", except the first one, which is actuated by the process of "line following". The start point of the first step is the identification of sides (out of the plane contour of the object) belonging to areas that have no more adjacent areas other than the identification one, but only faces and bodies.
Then, starting with this data list, the "line following" procedure allows finding the plane contour of bodies, even it is concave, non-stellar, intrinsic or multi-connected (in the last case. Obviously two distinct and disjointed contours of bodies are available, the "region growing" procedure helps reconstruct bodies; notice that, whenever a new plane contour is touched, the same should be considered as already used, hence belonging to the same bodies of the starting plane contour

5. OPEN QUESTIONS

At present, the question is still open, as to find partial overlapping of faces of different bodies, comporting a face to the other (so, fixing a number of contact point) and decomposing major faces in parts able to match minor faces and their possible non-covered complementary parts.
At a first glance, the simplest, geometrically compatible, configuration of a couple of convex bodies appears as flows:

❑ a face is totally inside the other;
❑ a face lies inside another one, but vertex of hers touché a contour of the other at a vertex;
❑ a face lies inside another one, but a vertex of hers touché the contour of the other on a sideline;
❑ a face lies inside another one, but it touches with one of her sidelines a sideline of the other;
❑ a face lies inside another one, but it touches the sideline of the other also with a vertex;
❑ a face lies only partially inside another one but it overflows only on one side;
❑ a face lies only partially inside another one, but it overflows also on a vertex.

Again, visual evidence is not easy to be started as univocal inferential rules
So, we need find new geometrical matching strategies: however, complexity is really severe, without the hypothesis of convexity for bodies and faces. But it is quite evident that the said hypothesis is not true in any case, as the physical world offers a variety of concave bodies or faces, (also non-stellar and sometimes multi-connected ones).

It is remarkable that many considerations able to allow quick choices, avoiding the Boolean computation of all possible combinations-out of which the ones geometrically possible should be taken –have a wide usage of numbers 7, 17 and 32
Further simplifications could be suggested by a wide range of arguments from Literature, Arts, as well as the Theory of numbers or the Gesthalt philosophy.
Although we should never forget the arbitrary of numbering, still fancy and rigor are both necessary for a sound evaluation of the world.
Finally the present considerations want only to express a qualitative point of view, while mathematical implications would often require to proof complex theorems

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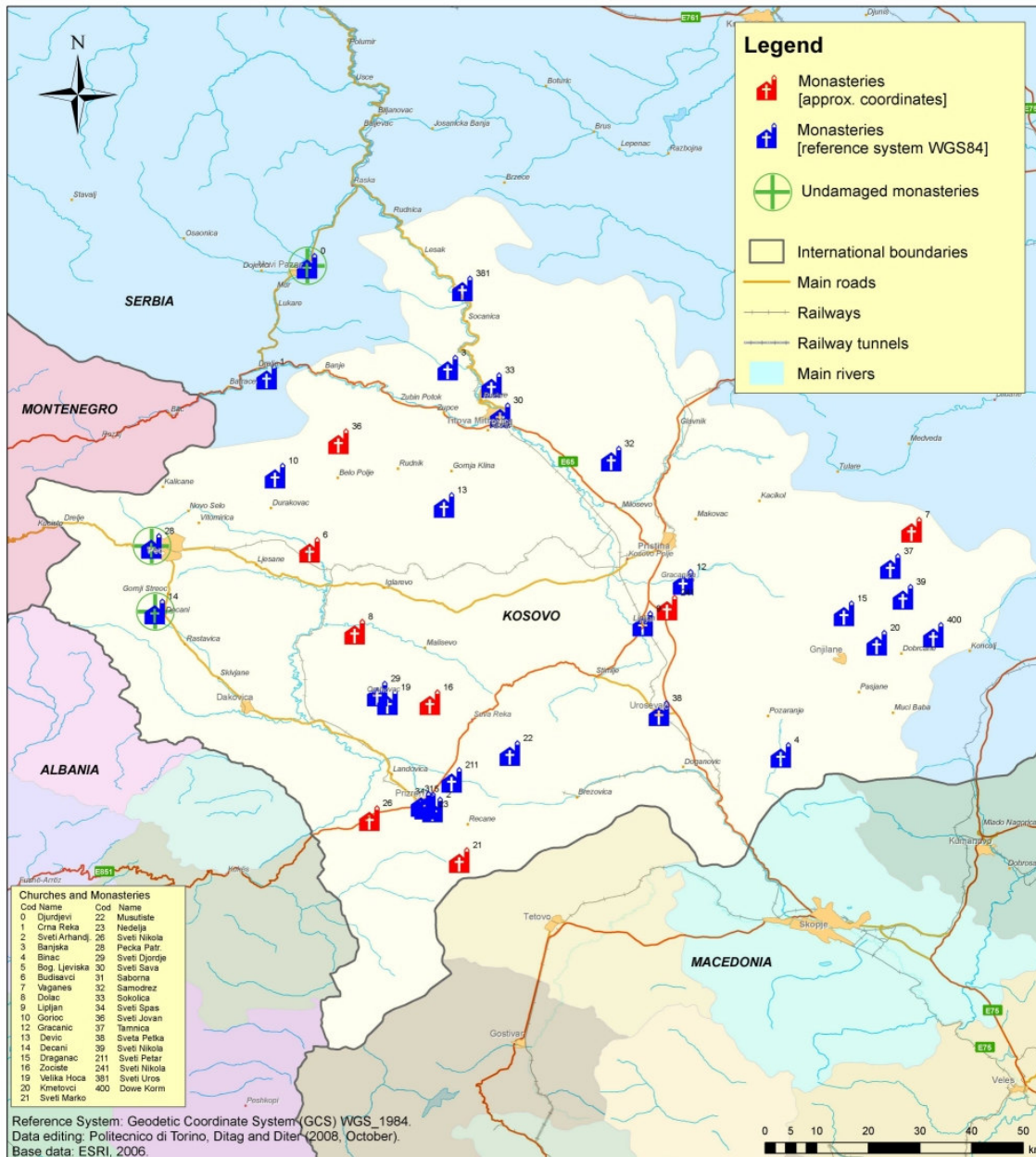Penn State University Library, Digital Chart of the World,
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Fig. 6 Monasteries and churches of the GIS