ADVANCED GIS TECHNOLOGIES TO SUPPORT GEREREFERENCING OF THE CULTURAL HERITAGE

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ABSTRACT:

The project "Georeferencing of Architectural Heritage" is part of a larger Regional Program of Development that provides the carrying out of the management aim *"Achievement and optimization of the Informative System of Lombardia for the Risk Chart of Cultural Heritage"*. The project aims to build, as pointed out in laws, the co-ordination of activities and specific competences that are necessary to reach the definitions of rules, methodologies and specific techniques for the Georeferencing of monumental heritage in the entire regional territory. Georeferentiation means the base to manage the cultural heritage integrated by environmental thematic coverage of soil characteristics and risk (multiple indexes, …) related to the physical and spatial geographical position of monuments. Here are related different methods for the acquisition of the geographic position of monuments, the spirit of draft proposal of specification and guide lines, new perspectives opened by the research and new fields of apply.

1. MANUSCRIPT

Introduction

Our research - part of the larger study into preparation of a Risk Map of Cultural Heritage - has already been studied by the research group of the Operating Unit of Polytechnic of Milan, inside Cofin00[1]: Cofin00[2] dealt with digital methodologies of surveying, GIS and multimedia networks for architectonic and environmental objects. The experiments conducted in this field, not yet concluded, have uncovered problems inherent to the research initiated, but at the same time, have shed light on still other issues relating to aspects associated with protection and what is commonly known as the "Risk Map". The research has been developed inside a second co-financed[3] project, that is begun the last year and will be concluded the next year, and is the natural following of the last project.

The contemporary Research with the IRER (Regional Institute of Economic Research, property of Region of Lombardy) on the issue of measuring and georeferencing protected and non protected cultural objects (pursuant to Law 1089/39) located in Lombardy, has proven the appropriateness of the themes studied by Cofin and, at the same time, has emphasised other very different problems, ranging from the space dedicated to survey procedures, digitalization, georeferencing, and classification right up to the need to apply new instrumental survey technologies, as well as application of appropriate, already existing maps to prepare the "Risk Map".

"*Study and experimentation activities in the field relative to the definition of methodologies, regulations, and technical specifications for georeferencing and photographic documentation of the historic architectural heritage of the Region of Lombardy (Restricted Property in terms of Law*

1089/39)" is the title of the research contract carried out between the DIIAR and IRER.

This is a strategic project for the Region[4], the field of apply of georeferencing campaigns is represented both by monumental heritage protected by law and under the supervision of the Superintendence (about 9000 monuments in the only Region of Lombardy are protected with declared protection decree), all the public architectures with more than fifteen years (for law they are automatically protected and are not included in the upper set, there is no list) and by heritage non protected by law, with recognized historic and artistic value included in the map of risk of cultural heritage.

The experience acquired through MURST research, combined with this other specific experience, has allowed us to get a good handle on the problem, with a complete awareness of the complexity of the problem, its multiplicity, and consequently, the difficulties inherent in problem-solving. From here, the reasons behind this research.

The main targets of the project can be summarized in the following steps:

1. defining methodologies and standards of georeferencing (photographic documentation included) inside the Regional Territorial Informative System (SIT).

2. testing instruments and georeferencing rules and methods based on numerical cartography such as CTR, orthophotos, or based on direct surveying using low cost new portable GPS instrument, …;

3. evaluating costs and management aspects in different hypothesis;

4. testing the process in *pilot* - area with different territorial characteristics (cities, mountain, hill, lake landscapes);

5. giving geographic coordinates of monuments obtained by digitizing and comparing[5] their features on Regional Technical Cartography (CTR, Orthophoto "IT2000 at scale 1:10000) and, especially for historical urban centres," on other bigger scale cartographies (scale 1:2000, …);

6. beginning to build up draft guide line and specification due to support the work of the operators of the georeferentiation campaigns on the territory, Province by Province: Guide lines are usefully considering that the informatic level and carthografic skill of the base user-operator will be quite low, since they are expert in cataloguing cultural heritage;

7. developing system of User Friendly procedures to guarantee an amusing degree of suitability to the low level application: for this matter it has been supposed some phases (Phase A, B, C, D, E) delegated to the base user operator and some other managed - after the base collection data - by the system Administrator of the Cultural Heritage SIT (Phase F, G, …).

2. Design of the GEODATABASE

A starting point is the design and georeferencing of a sample objects based on GIS technology constructed on a sample of some 1000 protected objects, with different characteristics and distributed all over in different context in order to compare different methodologies, testing technologies, and to evaluate also time and costs of localizing and identifying work.

In this sample, it has already faced and experimented on the following topics:

- *design of a GEODATABASE;*
- *lists: logical arrangements of the structure of the archives (Background information_OBJECT, data updating, Background information_Hierarchy, ...);*
- *sequences and procedures of different operative phases;*
- *proposal of different case of georeferencing condition in function of the different maps (raster-vector) referring to the support map in the different municipalities (CTR and IT2000 1:10000, CTC 1:2000, cadastral map sheets,...), as a basis for digitalization and georeferencing the objects; it has been made different level hypotheses in order to guarantee an homogeneous output data at the regional scale but improving the quality of representing Manu facts obtained by detailed scale in case of availability of large scale cartography;*
- *identification of the different operative phase of work;*
- *identification of different levels of georeferencing:*
    - *BASE Georeferencing Level:*
        - *1. Level I - POINT georeferencing (rapid);*
        - *2. Level II - AREA georeferencing.*
    - *STRUCTURED Level: HIERARCHICAL DESIGNED Georeferentiation:*
        - *1. Is - Punctual Structuring;*
        - *2. IIs - Areal Structuring.*

2. GEOREFERENCING METHODOLOGIES AND DESIGN OF THE GIS PROTOTYPE OF SPECIFICATIONS FOR DRAFTING THE RISK MAP OF CULTURAL HERITAGE

The research has allowed us to identify some specific certainties such as the use of laser scanning, palm GPS, assessment of the different available cartographies, design of the georeferenced data on different levels, all of which need deeper investigation and validation. .

Therefore, we can see how the research must centre on definition of the georeferencing methodologies of the cultural objects, definition of specific techniques still to verify in order

to reach a proposal of a "typical" specifications and finally, testing criteria for the system constructed.

Three the lines of research that combine on different levels and scales along the common support structure of the Map of Risk, involving a complex interlacing of survey, representation and GIS problems and aspects.

All three have a marked theoretical-methodological nature, a common need of experimentation on the field, and a strongly applicative value in terms of on-field-validation of the hypothesised methodologies. A need shared by all three is to identify appropriate test areas to set up with the local authorities and other Organizations.

1. The first involves georeferencing, design and construction of a GIS to support the Risk Map of Cultural Heritage, starting with sketching an outline on a set of file-cards based on standards developed by the ICR (Central Institute for Restoration) and on different cartographic and information bases (geographic and database).

2. The second involves generating advanced 2D-3D models and complex raster/vector surfaces for the "at risk" cultural objects and contexts to support identification and definition of parameters of vulnerability, scheduled maintenance and , preservation, routine on-site work.

3. The third deals with testing and experimenting new technologies (GPS palm System, laser scanner, …) and expeditious systems of data acquisition, identifying appropriate filed of apply: perhaps laser scanner technology, even metrically reliable and quickly, still reveal many unresolved problems in the modelling phases and processing the point clouds which must be faced.

4. At last, implementing[6] WEB GIS agile access, consultation, distribution and transferring of GEODATABASE remote located. Only in this way this information become really available to professionals, operators, specialists, local authorities and government departments as well as citizens involved in protection efforts.

2.1 GEODATABASE structuring: Operative Working Phase

All the procedures described has been organized in different Phases (A, B, C, D, E, F) of work to be made by different operator who will make the cataloguing and georeferentiation of the Cultural Heritage Province by Province.

- Phase A. Inspection and survey of the data on-site. It has to be carried out to update the catalogue and the archives related and to locate heritage: circumscribing on map the perimeter of the monuments (in case of Level II) or simple locating Point (approssimatively the centroid if it's inside the object) in case of Level I;

- Phase B. Definition of digitalization operations and georeferencing: it has been treated, among all, verification of the procedures and information. Geometric condition of congruence, accuracy prescriptions, referred to the map tolerance, and outlining in the digitalization phase. Auto-consistency polygon, adjacency conditions. Automatic generalisation to progressively smaller scales (from 1:2000 to 1:10000, from 1:10000 to 1:25000,….). Phase C. Editing DBASE (Name, ID_BENE code number assigned, Typology, Address updating, Maps, …).

- Phase D. Filing the photographic documentation and integration into the GIS.

- Phase E Automatic extraction of Gauss Boaga (E,N), national cartographic coordinates, of the Point or of the centroid in case of Polyg .

- Phase F Extraction of the orthometric attribute. In particular, our research studies the automatic bundling methods of the individual objects of the level extracted automatically by GRID data obtained on a ArcInfo environment, resulting from processing the DTM available inside IT2000 Map.
- Phase G: Region structuring

This level allow to structure Geographical Data and relative Archives by HIERARCHICAL DESIGNED georeferencing that include the 3 logical classes of objects: Individual object, Components and Complexes.

In this level are described REGION based procedures. Examination of case studies typical of the lists of objects and flexible adaptation of the structuring procedures to their characteristics (complex objects without elucidation of their component objects, component objects without the complex object, adjacent components, complex objects with relative component objects, individual objects).

2.3 Georeferencing with GPS Pathfinder Pocket System

The research we propose, studied:
- implementation of the Risk map with object Coordinates (E, N, q) acquired with the GPS Pathfinder Pocket System;
- methods for handling and processing the data;
- test of accuracy and processing protocols: this phase is particularly delicate since the relatively low cost of the instruments, the high manipulability, and ease in using the system will encourage its wide spread use throughout the sector; this could bring about the risk of superficial methods of processing with uncontrollable errors, especially with the less experienced user. Therefore, there is the need to disseminate basic processing standards.
- real time connection methods, by means of experimentation and targeted testing in zones having different morphologies (mountainous, hilly, flat plains regions) for acquisition of the differential correction with permanent GPS stations sprinkled around the territory in order to improve the degree of accuracy of the data acquired. Definition of connection protocols via modem (radio and GSM) and the Internet; use of permanent stations for realisation of Virtual Reference Stations (VRS); definition of a Master Virtual Station[7].
Useful of Palm GPS technology has been tested in both direction:
- remote updating DBASE with the data collected on site avoiding manual transcription error, eventually using Palm with support cartography to make sketched digitalisation;
- georeferencing (G.) by acquiring directly 3D coordinates position for particularly set of manufacts. Filed of possible apply:
-archaeological sites, complex and components;
-archaeological routes, protected itineraries, open museums, … not registered on the map;
-generally in the cases where is possible GPS be positioned to have signal coverage, over the objects, or inside (for architectural manufact this condition is not verified, so it's very limited for historical centre) for set of well that needed to be G. obviously *in absence of map*.

2.3 3D Environmental model to build 3D georeferencing and topology : aggregating attribute to GEODATABASE

- Automatic processing and bundling the geographic data for the Risk map of the Cultural Objects.
We will conduct experiments with the following objectives:
- methodologies, specifications and automation procedures for extraction, bundling and integration-correlation of environmental and geographic information on the individual objects or complexes currently at risk;
- generation of inclination charts, solar exposition, acclivity (information associated with the altimetric description of the terrain), using GRID topological data structures of the 3D model and area structures extracted by uniform bands, related with the topology of the cultural objects, in an indexed and attributed format for easy consultation;
- interrelationships with themes of other origins (geological, subsoil, hydrographic, overflow, landslide risk, hydro-geological instability….) to generate vulnerability indices and parameters;
The idea is to improve on the idea of merely cataloguing and classifying in order to better support the comparative work in evaluating the phenomena of accelerated decay and instability, in appraising the transformations taking place over time, in making historical assessments of the data, and providing support to the decision-making.

2.4 Experimentation: usability of Cadastral Map in Georeferencing

The research intends to pursue experimentation in the direction of using cadastral data, looking for context where the Map of Risk may be used. In fact, inside Map of Risk, once any risk level or index has been uncovered, tracing back the properties will be a mandatory step. Two the settings of use are examined:
- I. BASIC georeferencing using numeric cadastral charts;
- II. ON LINE use at a later time of the cadastral sheets from WEB GIS of the cultural objects.
Problems to face:
* geometric identification of the restricted area by means of cross-referenced research of the Superintendent (list of the protected cultural objects, protection decrees, …), of the Registry and cadastral office;
* check of the procedure of integration between cadastral cartography - parcel – registry – "protected by law" heritage: finding the protection Decree, identifying the parcel numbers and respective certificates on line.
* evaluating if the use can be concretely forecasted in differentiated times and, at a later time, with respect to an initial generalised georeferencing on all the cultural objects and in this case, according to which methods.
In case of protected monuments, only from the single decree is possible to identify restricted area, in this case through number of parcel; from the parcel to the cadastral map and to the property registry.
And in case of all the other monuments, once extracted from the risk area the "at risk well georeferenced", is possible from the cadastral map, to find the parcel number till to the property registry.
In the Italian case, digital Cadastral Maps are inhomogeneous, partially updated. In Lombardy only 3 provinces (Milan, Lodi, Cremona) provides vectorial map, for the other there are raster map with geotiff file only around some extra urban areas. And so on. So it's impossible to make responsible of digitalisation and georeferenciation of map (solving transformation problems, algorithms, world file, ...) the operator of the G. of Cultural Heritage. What is possible and has been done, but only in case of expeditious and punctual G. with low cost necessities, is to delegate to the Institute of Cadastre (Territorial Agency) the work to identifying and georeferencing on he map but only by the office without on site campaign and collection of database field. One great problem experimented is the difficulty to locate monuments on the map without on site campaigns, since

address is not complete (civic number, …) and in case of high density built area of Historical Centre.

2.4 ON LINE RISK MAP (WEB GIS): TOWARD REMOTE INTEGRATION OF THE "SUPERINTENDENT, CADASTRE, REGIONS IS"

Our research aims to channel a logic that replaces the current system of dissemination of the research results and the duplication of the data, against a systematically accessible and constantly revisable support. Setting an on line WEB GIS structured in a Client/Server architecture that can be queried and is user-friendly, responds to the need for a logic supporting the broadest possible policy of "participatory" or "shared" protection, for a precise and specific transfer of the information to the various subjects in charge: the citizen, tourist, professional or civil servant, the Ministry for Cultural Heritage and Activities, the Region of Lombardy, Superintendents, local authorities, among others…. In the event of a possible future expansion of the categories of protected objects, or other categories which might be future subjects for such risk analyses, this arrangement would enable an immediate extension of the methodology to include other cases.

Therefore, our research proposes to:

*develop an 'on line' access programme from remote locations to various archives associated with the Risk map;

* experiment on line consultation of cadastral information – i.e., maps - as part of an integrated management involving "cadastre-municipality-region-Superintendent and registry", in a client-server architecture;

* examine the technical assumptions on which to base an agreement between the public authorities (Territorial Agency/City of Milan - Region of Lombardy);

*develop the methods for consultation/bundling/identification of the certificates and the Urban Property Units; study the methods and protocols of use of the maps by means of an integrated network of certification of the parcels, which can be consulted today at the government offices through the SYSTER system;

* identify a process of cross-referenced information consultation, in order to make information available ONLY WHEN NECESSARY, in different degrees of detail.

3. CONCLUSION: GUIDE LINE AND, THE PROPOSAL FOR DRAFT SPECIFICATIONS.

The problem was already faced along general lines as part of the Research. The numerous problems that emerged required not only technological and methodological exploration, but demonstrate the need for procedural guidelines that must be defined by a specifications.

The result of the research will be published, in the form of guidelines-specifications-procedures, within the present year, on a book with the supervision of Region of Lombardy, titled "Instruments for georeferencing historic artistic architectural heritage of Lombardy". The first campaign of gereferencing based on guidelines it has been carried on during the current year (1500 Manufacts in Lodi province). The filed of work will be the best examination for a concrete process and to affined the methodology for the future. That's to say making efforts - only at the beginning - to get certificate georeference GIS.

1. Some specification, geometric condition, or concepts are taken by typical procedures inside the cartography specification, large scale over all (tolerance, geometric congruence, adjacency, auto-consistency of polygon, based on connectivity topology, …) relative to Phase B.

2. Other are procedures 'suggested' to avoid classical error of cataloguing and manual transcription (i.e. closed vocabulary in DBASE Editing, Auto Label to control denomination and title of the Monuments and to the ID_BENE Code Number (Phase C).

3. Other are description of procedures (command by command sequences) to support and guarantee the Quality System of GIS: this work is in fact   dedicated to base user operator with low level knowledge of CAD and GIS SW. Data location, Standard of File Name, Shape file name, are so defined , and so on.
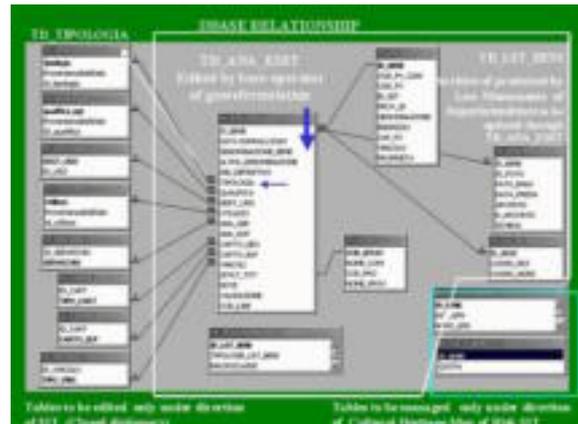

Figg. 1-2. DBASE related to GEODATABASE The TB_LST_BENI is the List of the Archive of the Protected by Law Monument

Fig. 3. TB_ANA_EDIT Table and detail of closed vocabulary (typology, occupation degree, …)
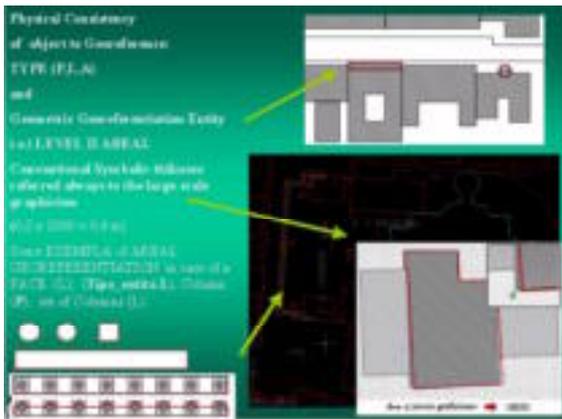
Fig. 4 Some Exempla of Areal Georeferenciation in case of a FACE (**TYPE "L"**), Column (**P**), set of Columns (**L**)
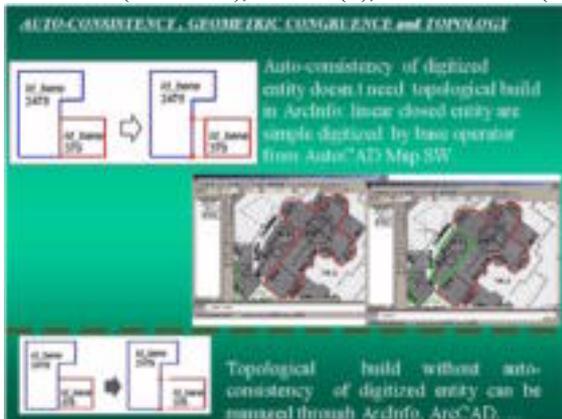

Fig. 5. Example of Geometric digitising condition
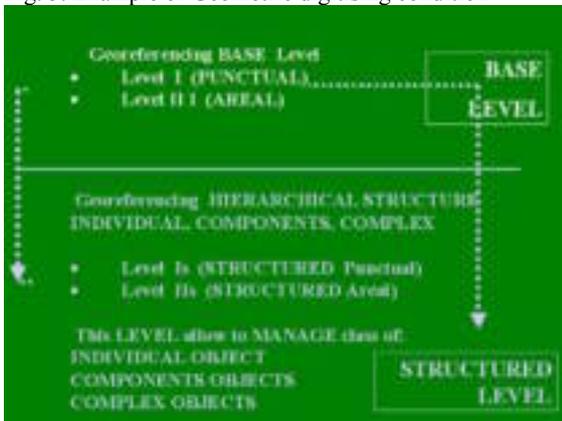

Fig. 6. Relation between Base Level of Georeferencing and Structured one built on the BASE Level
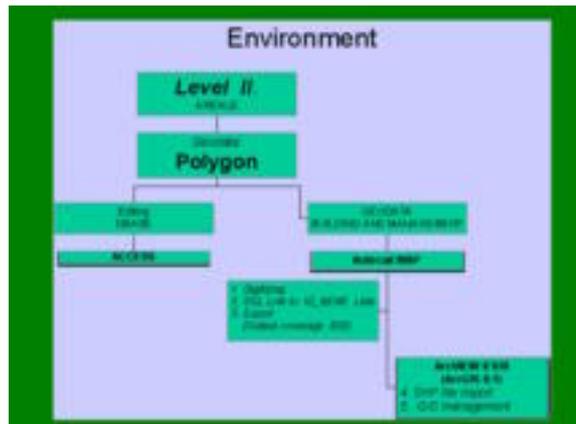

Fig. 7. Level I (PUNCTUAL) : environment

Fig. 8. Level II (AREAL) : environment

Fig. 9. Used instruments for experimentation (2001): Trimble Pocket GPS Pathfinder Systems connected to iPAQ Pocket PC
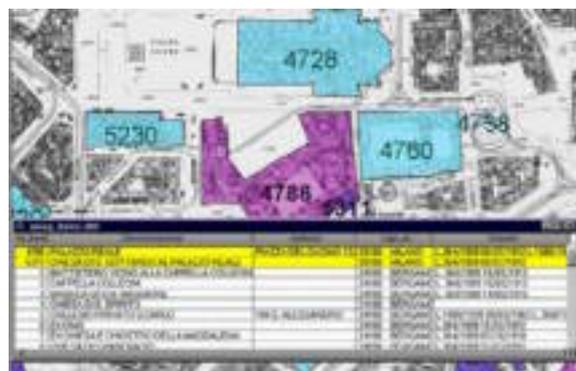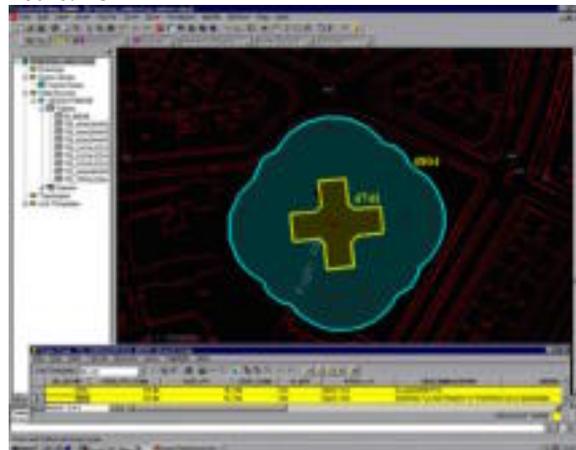
Figg. 10-11-12. Samples of aggregation typologies of objects (individual, components and complex) to be managed by Level IS through REGION procedures
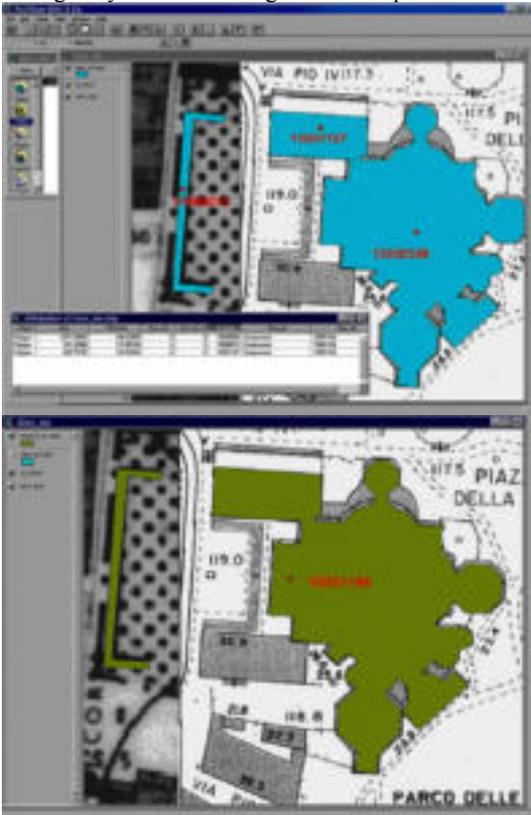

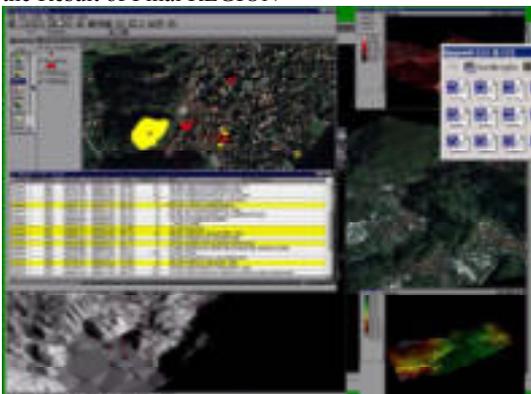Figg. 13-14: Separated object components and the Result of Final REGION

Fig. 15. 3D model: slope, solar exposition, and 3D aggregation of environmental thematism to the Attribute table of the Polygon SHP (i.e. slope)

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[1] COFIN research projects are co-financed by MURST (nowadays renamed MIUR, Minister of University and Scientific Research) and by the Universities through own contracts research.

[2] "Digital survey methodologies, GIS and multimedia network for Architectural and Environmental Heritage" is the title of the COFIN00 national research that has been co-financed (Scientific Resp. is Prof. Carlo Monti), "Use and integrated processing of data and models in a 3D GIS on line, with interactive navigation" is the title of the specific research developed by the Operative Unit of Milan.

[3] "Instruments, tools, operating and innovatory methodologies for the survey and the management of Cultural Heritage to support development of the Risk Map" (COFIN02).

[4] The programme of Georeferencing historic and artistic manufacts inside the Risk Map of Cultural Heritage, will be further tessera of the existing regional SIT (informative Territorial System) managed on ArcInfo, ArcView/ArcGIS Esri SW.

[5] The results of comparison between different cartographic support has been related in the paper presented at CIPA Symposium 2002, held in Corfù, Greece. Therefore, the result is that there are different cartographic support, due to their differing scale or methodology of their design (cadastral in Cassini-Soldner projection, the other in Gauss Boaga, …) but however, are all equally useful for different purposes, and can be used related one to the other. Region Lombardy preferred to digitise polygons from IT2000 since it is the most recent map, but veryfyng the congruence on the CTR that's the common base of Map of Risk. The same thing in case of large scale map availability /raster-vector), veryfyng results with CTR and recognizing the object on IT2000.

[6] This step is programmed for the next year on the base of analogue experience carried on by authors in Web GIS development in Historical Centre.

[7] Tests has been already carried out and are partially on course in collaboration with the Unit of University of Brescia, Prof. G. Vassena, inside the mentioned COFIN.