

MANAGING THE ARCHAEOLOGICAL RISK THROUGH VIRTUAL REALITY

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KEY WORDS: GIS, Predictive Modelling, Landscape archaeology, Virtual Reality

ABSTRACT:

In the last decade 3D technologies have become a very effective means for managing and interpreting archaeological data. A better way to perceive, understand and communicate Cultural Heritage has been achieved through VR applications, which have enabled archaeologists both to make reconstructions of original landscapes and to put artifacts in their original context. Furthermore, the pervasive growth of the Web has led to a massive availability of digital contents, even in the field of CH, that can be accessed by a broader audience of people in an easier and more intuitive way.

The case study we are presenting is meant to demonstrate how important can be the contribution given by Web3D technologies for communicating specific research aspects, such as the ones connected to the GIS-based spatial analysis applied to the archaeological landscape.

In this sense, a research project has been carried out in order to get a final 3D-predictive model for detecting archaeological presence in a portion of the Pisa coastal plain, implemented in a Web oriented VR system. The final user is able to navigate the model in real-time and observe different thematic layers, such as the distribution of the archaeological sites, maps of lithology, land use and, finally, the assessment of the archaeological risk.

1. INTRODUCTION AND PREVIOUS WORK

As a part of a PhD research, this project has started from the analysis of different case studies related to the application of predictive modelling all over the world. The purpose was to try to understand how much confidence would be provided by the predictive model to the final users, in terms of accuracy and precision. Though many case studies have been analysed (Wescott and Brandon 2000), most of them concerned the application of predictive modeling in a bi-dimensional context, without considering all of

the elevation features able to influence the site distribution in the territory.

The study context is a Holocene, alluvial plain made up of sedimentary deposits carried by Arno river during the last centuries, where a complex system of lagoons and channels formed the original palaeo-environment. Over one hundred sites, dating from late Paleolithic to the end of Middle Ages, have been detected in this environment by means of different diagnostic techniques (remote sensing analysis, boreholes, historical cartography, literary sources)(Pasquinucci 2000). Nowadays, most part of this territory (located between the cities of Pisa and Livorno), is occupied by agricultural land, although an increasing portion of it is going to be

interested by new development works that could compromise the preservation of the still undisclosed archaeological deposits underground. That is the reason why the Pisa coastal plain constitutes a good case study for applying a predictive model: here a conspicuous number of sites could be hidden in the still un-surveyed portion of the study area, which is too wide to be investigated by using traditional prospecting techniques. In this sense, the predictive model, starting from a statistical hypothesis, tries to 'predict' the most suitable areas for finding new archaeological sites, excluding from the research a wide part of the territory in which the probabilities of new finds are fairly low .

The research, based on the data collected by the University of Pisa, chair of Ancient Topography, in over twenty years of study, has started from the analysis of the archaeological record and the setup of an inductive kind of predictive model within a GIS platform. Subsequently, the outcoming model has been tested through different steps, firstly on the internal dataset, and after on new, independent, external data, collected on the field. Afterwards, a 3D representation of the model has been derived from the Digital Elevation Model and then exported to be visualized in a VR system. One of the most exciting aspects of this research is that it uses a VR technology which allows to present the content, with minimal additional efforts, either on immersive installations or embedded in a web page, in order to reach the widest audience possible.

Indeed this is a clear strength under the communication perspective. As we said, the quick spread of broadband connections, streaming and pod-cast channels through the Web, has enormously increased the possibilities of uploading complex 3D contents, and this turns out to be a very interesting chance to communicate cultural aspects related to the study of landscape archaeology.

2. OUTLINE OF THE SYSTEM

2.1. Setting up the Predictive Model

The first step in the setup of the predictive model has been the collection of the cartographic dataset related to the Pisa coastal plain, both in raster and in vector format. Basically it consists in 1:10K scale topographic and orthophotographic maps, from which specific thematic layers have been derived, such as the lithology and the land use. Moreover, three different layers have been added up, obtained from a Digital Elevation Model of the study area: elevation, slope and aspect maps.

Once the cartographic dataset has been implemented in a GIS geodatabase, it was necessary to think about the best strategy to get the final predictive model. After analyzing several case studies employing predictive modelling, we decided to use an inductive approach, which gets the final outcome starting from an existing sample of known sites, by assessing the influence exerted on this sample by different environmental variables (Wheatley and Gillings 2002).

In order to accomplish this, five 'predictors' have been identified and then implemented in the GIS spatial analyst tool. The selection of predictors has been made based on the existing correlation between known sites and classes of each predictor (the higher was the density value expressed by each class, the higher was the weight to be assigned to it). The variables selected as predictors are therefore: lithology, land use, elevation, aspect and slope. In order to get a more reliable model, the original sample of known sites has been split in two parts, 'training' and 'testing', on which we set up two different predictive models that afterwards have been compared and verified in their discrepancy level.

All of the predictors have been processed through a weighted overlay algorithm, which produces the final outcome by the sum of the different weights and scores expressed by each one of them. Subsequently, we obtained

the two different ‘training’ and ‘testing’ risk maps, both expressing three different levels of probability/risk of finding new archaeology, from level 1 (low risk), to level 3 (high risk) (Fig. 1).

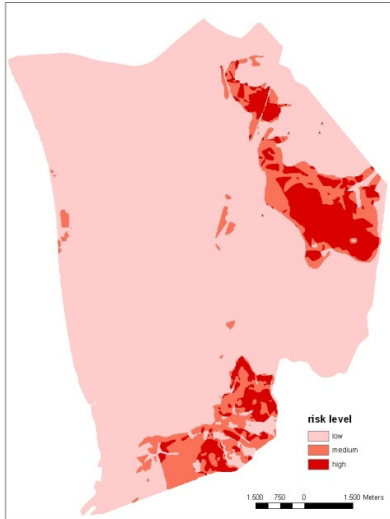


Figure 1 training model

One important aspect to be considered in such a kind of modelling is the need to test the outcome data. As aforementioned, a predictive model is a statistical hypothesis that needs to be tested in order to establish its level of confidence. Generally, the test of a model should take place through different stages: first, it has to be based on internal data, the same on which the processing has been performed; afterwards, it has to be carried out on new, independent data, which archaeologists collect from the field.

In the Pisa coastal plain project, the first stage of testing consisted in the measure of model performances, which is the degree to which a model correctly predicts the presence or absence of archaeological remains. A high standard of performance, defined by a gain value very close to 1, is based on the calculation of the so-called Kvamme’s gain, defined by the algorithm

$$G = 1 - (Pa / Ps) \text{ [Verhagen 2007]}$$

where Pa corresponds to the area proportion of the zone of interest and Ps to the proportion of sites found in the zone of interest.

When the final value is close to 1, it indicates a good working model in terms of accuracy and precision. In this case we obtained, both in the training and in the testing model, a very good standard of performance related to the high risk level areas, resulting in a Kvamme’s gain values of 0.980 and 0.888. Subsequently, a further internal testing has been applied to the two models, in order to quantify their difference and discrepancy levels, by means of the following algorithm:

$$K = (Po - Pe) / (1 - Pe) \text{ [Verhagen 2007]}$$

where Po is the observed agreement and Pe is the expected agreement between the two classifications. The final value obtained, 0.952, seems to confirm a nearly complete agreement between the two models.

Finally, as for every statistical hypothesis, it is important to test it by verifying the discrepancy between a starting assumption and the available data, where we consider as available data the dataset made by new, independent elements not used for building the model (Verhagen 2007). In this sense, statistics help us in answering the archaeological questions which led to the realization of the predictive model (Fletcher and Lock 2005), making a quantitative assessment of the level of confidence to which archaeologists can look at.

Subsequently, in order to collect new data for testing Pisa coastal plain model, a surface survey has been carried out in a small sample area that led to the discovery of new archaeological sites.

The final strategy was to survey a small sample area, corresponding at least to 10% of the total study area, that in terms of sample size is sufficient to give reliable information about the total population¹. The choice of the sample has been based upon un-surveyed areas and the three different levels of archaeological risk or probability, on which the study contest had been divided.

For that reason, sample area has been allocated in three fairly equal portions of land

¹ See once again Fletcher and Lock 2005.

corresponding to the three different probability classes, with a slight prevalence of the low risk one, attested around 40%. Indeed, in testing a predictive model effectiveness, it is important to investigate also the spaces where the model predicts sites should not be present, as a warrantee of impartiality in the final data collecting (Banning 2002).

Survey has thus been held in a systematic way, trying to cover all of the land units across the sample area by walking in regular transects, with field walkers locating 3-5 meters each other. That allowed a nearly total coverage of the land, so as not to miss any possible archaeological find, however small. Final results show us that a total number of eight sites have been gathered, with a clear prevalence for finds pertaining to high risk areas, in which six sites have been identified. Sites are almost all dated to the Roman age, with only an exception, dated to the late Paleolithic. Even though we cannot evaluate these results in a statistical way, it is clear that the very most of the discovered sites falls in the highest level class of archaeological sensitivity, while only two ones have been identified in medium/low risk areas.

2.2. Web 3D implementation

Once the predictive model has been set up, it was ready to be implemented in a Virtual Reality system. The 3D model was obtained from the Digital Elevation Model by interpolating contour values and elevation points. As we previously said, the final purpose of this project was not just to reproduce a 3D predictive model, but to create a complete virtual archaeological landscape, in which the final user is able to navigate, by switching through different layers and interact with the archaeological record, looking at the existing interactions between it and the environmental features represented.

Therefore, multiple layers such as lithology, land use, topographic and orthophotographic maps have been turned into 3D layers and georeferenced at the same coordinate system, by means of the 3D analyst extension of GIS.

With regard to the representation of the known sites, one of the main purposes of this

virtual representation is to provide users with an effective way to visualize and interact with the archaeological dataset coming from GIS. With this aim, the symbology of the archaeological record has been thought in order to give an immediate perception of the chronology. As final users are unnecessarily supposed to be sector experts, we chose to simplify the archaeological record by subdividing it into three main symbol categories, representing as many chronological macro-areas. Therefore, we started from distinguishing a Prehistorical, a Historical and a Medieval age, in which the 104 known sites pertaining to a very broad range of chronological classes have been classified. For that reason, we decided to put into the Prehistorical age category all the sites dating to the Paleolithic (middle and late), the Eneolithic, the Neolithic, Bronze Age and Iron Age. We put the Archaic, Hellenistic and Roman age sites into the Antiquity category, while the Medieval ones have been located into the Middle Ages category.

After this database allocation, we had to choose some representative, symbolic 3D models able to give an idea of the chronological phase they are related. For that reason, we found a very fast and effective solution by looking at the Google™ 3D warehouse, a Web repository where anyone can search for and download specific models, connected to the keyword the user has put in making the search.

Thus we finally used different three-dimensional icons to distinguish each site based upon its own original function. Moreover, a database stored information concerning the sites has been associated, as it usually happens in GIS, to every single model, so that it is possible to gather all the available data that have been collected and studied in many years of research: data that in the recent past could be spread just by means of specific publications, with a very low chance to reach such a vast audience, can this way be communicated in a faster, more intuitive and interactive way so that a broader range of final users can be involved in this discovering-learning process.

In order to make users easily understand the chronological distribution and the typology of the archaeological sites all over the study area, we adopted two main criteria in their representation: firstly, we chose to make an identification based on the chromatic scale, showing by means of the icon colour which chronological phase the site is pertaining to. We used green for Prehistory, red for Antiquity and blue for Middle Ages. Once the chronology has been identified by the user, it is possible to retrieve the original purpose which the site has been created for by looking at the shape of the icon. Whilst some symbols are representative uniquely of a specific chronology (it is obvious for instance, that a lithic artifact shaped icon will mark only a Prehistoric site), other ones are used to define different chronologies (for instance, an anchor shaped icon identifies both a Roman and a Medieval harbour).

Afterwards, each model has been exported from GIS as a VRML file. We produced different models, one for the terrain representation, made by the aerial orthophotos, one for the toponomastics of the study area, expressed by means of 3D text icons, and other models for the thematic layers concerning the land use, the lithology and, most of all, the mapping of the archaeological risk derived from the predictive model. Moreover, a terrain model with the overlapping of the 3D symbolic icons representing the distribution of the known sites across the Pisa coastal plain (Fig. 2) enabled us to obtain a complete representation of the present landscape of the study area.



Figure 2 3D icons representing the known sites

This virtual landscape integrates superimposed information related to the toponomastics, geological and land use aspects and the archaeological information represented by intuitive 3D symbolic icons expressing both the different chronological phases and the functions of the human settlement in this territory.

The model has then been converted in the AAM geometry format in order to be visualized with the XVR technology (Carrozzino *et al.* 2005). There are many interesting features in this kind of web 3D technology that can be useful in this specific research project. Our aim is to realize a virtual model that enables the users to perceive, through an easy-to-use learning scheme, the spatial location of the archaeological sites spread all over the Pisa coastal plain, and the archaeological risk draped on the 3D environment (Fig. 3). The XVR technology allowed us to realize a 3D real-time application where the different models

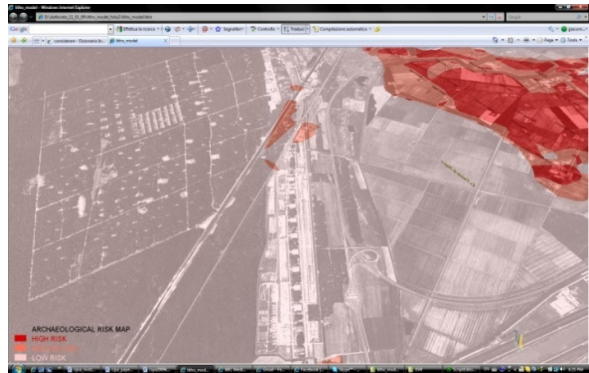


Figure 3 the final Pisa coastal plain model

previously obtained have been integrated and where it has been possible to set up a kind of web3D GIS. Users are free to navigate and move into the virtual environment almost without any limitation, just by dragging the mouse, and get information about the archaeological record by clicking on each three-dimensional icon, which helps in making people understand the sites distribution. Finally, apposite commands enable users to switch through different thematic layers, such as land use and archaeological risk maps.

3. CONCLUSIONS

The archaeological risk management, carried out with such a tool for analysis and communication, can be addressed to involve a larger number of subjects, thanks to the easiness in terms of use and visualization this model owns. Superintendences, university departments, local authorities, private entities could use this tool to observe, question, analyze the territory and know in advance which areas require a greater and widespread control, or in which areas future archaeological investigations are more likely to guarantee success, or what are the most appropriate areas for planning new infrastructure works. It is also important to note that a further objective of this research is to make the outcoming model an additional tool for increasing the knowledge about the territory and its archaeological heritage amongst the wide audience of non-expert people.

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