Expectations, Assessments and Capabilities in Managing Archaeology through GIS

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In the last decades computer application developed to improve the archaeological research. Among softwares for territorial analysis and for field record management the GIS has become today the most popular. Among many scholars, fieldworkers and students the increasing use of GIS caused the conviction to recognize a revolutionary tool that could improve documentation. Above all expectations are still raising. Among other scholars the same experimentations brought to a complete failure of the system, producing the idea that GIS is illusive and not corresponding to the daily application for the research.

In this paper, according some recent experience of GIS application, theoretical reasoning and a continuous comparison and exchange with colleagues, we want to discuss what are basic assessments and capabilities in managing archaeology through GIS.

Field research and data management are now becoming more and more complex with a strong increase in retrieving and considering archaeological records. Respect only few decades ago, techniques of excavation, sifting and collecting materials, sedimentological evaluation have so changed and made so different the way to carry out research and data treatment that we expect some revolutionary process. A decade ago many questions were rarely posed and now we can assume that is no more possible to continue the research without the help of digital tools, but many of us lost the perception of real capabilities of each own system, even if apparently considered suitable for the research.

The huge chronological gap from the appearance of GIS to the first effective applications in archaeology could be motivated for the difficulty to apply in contexts related to the past, with filtered and reduced data. Developed for application in the current world, the GIS can find very rarely similar completeness in archaeological data, usually limited to poor and partial information. The same scarcity brought many scholars to criticize even theoretical formulations of New Archaeology and particularly the unsatisfactory results.

Expectations from the use of GIS especially brought to an over-estimation and very often the GIS is considered as a "*deus ex machina*". We can on the contrary be more aware of real capabilities and work toward an improvement dedicated to the archaeological research, discussing some of the main points that make it works.

GIS is a powerful tool for analysis of correct and abundant data. From this view one usual recommendation requests that all the records maintain homogeneity, a concept that goes against the richness and the complexity of data. In the current research any limitation in organizing data is contrary to the effort in recognizing new information. Technically we can choose between relational database, the most used software for archiving data, and information retrieval, more open and sophisticated for semantic relationships, structured as nodal network. This latter software is still very poorly used in archaeology, not only because of commercial reasons, but especially because archaeologists fear the complexity of unstructured data. Traditional scheme is based on the rigidity of database fields, with the necessity to fit each information in prefixed categories.

Archaeology instead is made of several unknown information relating each other and hardly convertible to simplified scheme. Apart of these considerations most of GIS users work with a traditional database.

The total amount of archaeological records include several aspects of cultural and environmental set. The use of GIS can help in the analysis of these multivalent data.

The digital tool allows to manage huge amount of data: especially for numerical list, or images, geo-statistical analysis produce new results with the possibility to control, replicate and improve each interpretation.

The rapidity in executing these elaborations push to feed back the current research. In this case interpretative models are considered as possible explanation, and they serve as suggestion of modalities of continuation of the research.

If we should resume what are the main characteristics and capabilities of the use of GIS in the archaeological research, we can fix following points:

1. Recording: digital technologies (topographic survey, photographic documentation) applied together with the GIS allow to be more precise and less subjective;
2. Control: immediate application allow to verify coherence of records through retrieval and summarization.
3. Management: GIS allows to examine huge amount of data and obtain spatial representation according selections.
4. Analysis: thematic representation is a fast and minimal step of analysis of data through GIS. Higher complexity can be reached according diversity of examined records.
5. Interpreting:

5.1. stratigraphy: assemblage of data according chronological or structural phases;

5.2. simulation: hypothetical reconstruction of past

5.3. predictive: hypothesis of new addresses in the research

6. Popularization: edition and presentation through GIS and more generally through digital

technologies allow to share immediately archaeological data and at least with numeric elaboration to let other scholars control the path of selection and management of data.

GIS can be considered as revolutionary tool for archaeological research, not only because it can evaluate or multiply data, but because it press archaeologist to look for more contextual data.

Some fieldwork experiences as examples will be presented:

- 3d microstratigraphy on site excavation : the Bronze Age site of Montale (Modena, Italy)
- topology for cognitive archaeology: logic of the use of space in the early Bronze Age settlement of HD-6, Ra's al-Hadd (Sultanate of Oman)
- display of retrieved spatial information: integrated system in management of archives.
- landscape reconstruction: transformations of landscape in the Bronze Age in the territory east of Modena

GIS application in settlement excavations

Settlement analysis, especially through archaeological excavations is the best example of advantage in the use of GIS technologies. Field investigation requires high level documentation and results depend from the capability to manage several information in immediate time.

Combination of topographic survey with high technology tools (Electronic Total Station or Laser Scanner) and the systematic use of digital photographs allows to avoid long wait in the excavation and produces more precise and correct documentation.

Here we will present the experience of GIS application for the excavation of the terramara of Montale, a Bronze Age settlement with an archaeological deposit, 3.5 m thick (fig. 1a-1b) (Candelato et al. 2002, with previous bibliography and chronological setting). The following operating procedures were applied during the whole excavation, from 1998 to 2002: First operation requests that when necessary (entire area or detail) surfaces are photographed with a digital camera from zenithal position reached from a pole (fig. 2a) or from a metal structure fastened to the roofing frame (fig. 2b) . Each photograph can record a portion of the surface and it needs at least four points clearly marked on the terrain (usually coloured caps). Following step concerns the recording with total station of these control points, of any other required points for detail evaluation (significant finds or features), and of all elevation points. With a specific software[1] all the photographs are corrected geometrically and merged together to obtain an orthophoto of the excavation (fig. 3a). This is immediately printed in a specific scale (usually 1:20) and the product is used for a field registration of US limits, characterization of finds, first interpretative sketch (fig. 3b). This step is particularly significant for two reasons: the first is that it will be a paper printed documentation useful for evaluations on the field in the following steps of excavation or for the control during GIS data entry; the other is that most of archaeologists fear to loose digital information during the fieldwork. In this case the printed map will take the place of traditional handmade plans, without loosing any information.

This system works perfectly when we have almost horizontal surfaces with few thick or raising elements. The algorithm used for the geometrical correction is precise enough to obtain good result. In case of changes of altitude or of presence of high three dimensional objects, we need to proceed to define several reference plans with respective control points. The software will merge together the photographs with dimension correct for each plan. More difficult is the representation of hidden parts, caused by oblique angles of digital photographs: in this case the solution consists in taking more photographs until all the parts are visible.

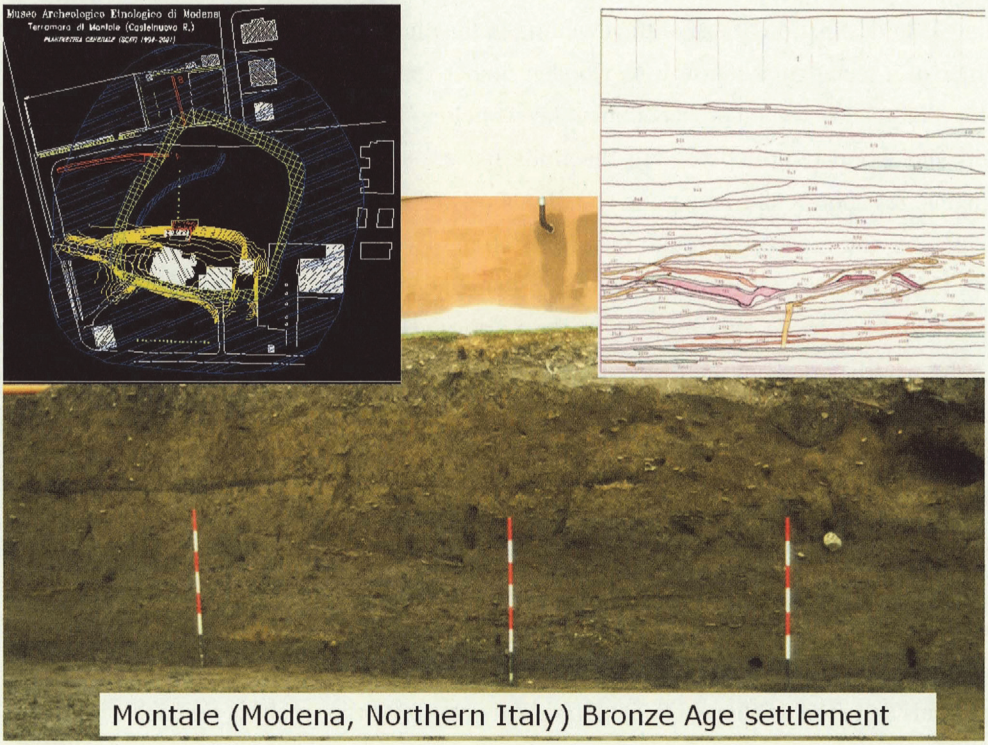
The other aspect of excavation concern techniques to retrieve finds, unit sample recording and other specific environmental sampling. According the decisions applied to the excavation the possibility to manage data in GIS will change. Sifting, flotation and finds selection will determine the interpretation of the archaeological deposit. Strategies in recording provenance are based on the establishment of the excavation grid with US as main provenance discriminant factor, followed by square unit and smaller topographic divisions.

Next step is the data entry of records in the GIS system[2]. No specific programming is required to improve the system, but with few Visual Basic codes it is possible to obtain more control or interaction with other software.

1) digitalization of US (layers, structures)
2) digitalization of finds
3) georeferencing of images
4) digitalization of other information (sections, functions)

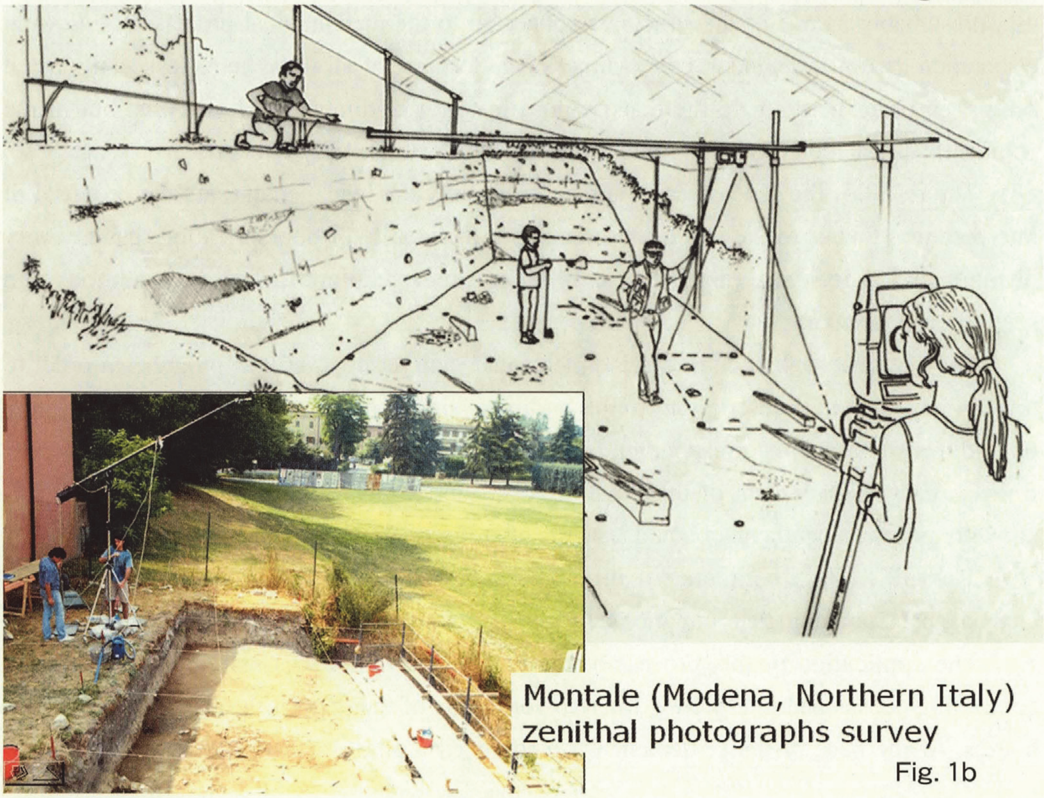
Main problems do not belong to technical problems of digitalization, but to what we intend for each recorded object. For this aspect the use of GIS is resetting some definition attributed to archaeological records and it is opening new aspect of the research. GIS allows to assist procedures of quantitative and distributive analysis, in order to locate activity area or latent (hidden) features. Trends of concentration, scattering and correlation of materials can be analysed in the general frame or for each category at different levels of detail. The results can suggest new hypothesis in interpreting the use of features. Geostatistical analysis find out the probability of certain variables occurring over an area where identifying every possible location would be difficult. It is based on interpolation methods to develop surfaces from measured samples and to predict values for each location in the same area. The real advantage respect traditional methods is again rapidity in the execution, but above all the possibility to control and to propose less subjective results.

An example of the use of geostatistical analysis is represented by the explanation of



Montale (Modena, Northern Italy) Bronze Age settlement

Fig. 1a



Montale (Modena, Northern Italy) zenithal photographs survey

Fig. 1b

changes in destination of use of the dwelling in the phase 633 and 707. In both these phases a corner of a rectangular house with wooden timber frame has been recognized: in the higher level (phase 633) several archaeological layers belong to this house and cover a floor made of mud and wood remains. Among the finds list appear many pottery sherds, some wood remains, few bones and numerous spindle whorls. The distribution of items collected in the excavation and recorded through the total station or collected from the sifting and recorded with US number and square unit, with a simple and fast geostatistical analysis, like density, located the supposed activity area in the north-west corner of the house (fig. 3a). Other spindle whorls spread in the rest of the structure, even outside, are interpreted for the lowest density as accidental scatter during ancient activities, or spread by postdepositional effects.

Under this phase the house is not so clearly defined, but it can be confirmed by the presence of another mud floor and from a general zoning of stratigraphic unit that follow the same previous orientation. In the layers related to this phase main characteristic is the discovery of several slags and metal scraps (fig. 3b). The accurate techniques of excavation aimed since the beginning to evaluate the presence of metallurgy process, but with the use of GIS it was possible to interpret better the meaning of craft activity. The collection of metal scrap and slags, tuyere fragments and moulds allowed to determine through the density analysis (of each category or as whole) the location of activity, confirmed by the discovery of a small pit, filled with charcoal and ash, presumably as one of the structures connected to the metallurgical process. A following elaboration tried to examine the three-dimensional location of all these items (especially metal scraps) in order to evaluate the density not only in a bi-dimensional analysis, but in the volumetric distribution (Cattani, Fiorini, Rondelli 2004, extended CD version).

The result of the process can improve drastically the management and the proposal of interpretation thanks to the rapidity of treatment, the quality of popularization (usually very difficult or too long), giving the possibility to other scholars to evaluate methods and scientific explanations.

For a correct evaluation of three-dimensional more effort is still in progress in order to transfer any analytical description from a bi-dimensional (or like it has been called 2.5d) to a three-dimensional more corresponding to the original stratigraphy (fig. 4a). Even if we are far from an easy management of these data, recent increasing attention to this problem, will allow to improve documentation and analysis of archaeological context.

The GIS, like a container of information can store and analyse sedimentological analysis, palaeobotanic determinations, results of flotation and sifting.

The application of this process to the entire excavation was extremely powerful in connecting phases and interpreting the transformation of the deposit or changes of planning houses. At the base of the settlement we recognized a phase with planked floors made of wood and mud, supported by long poles. In this case it would have been more difficult to obtain the same results with a traditional documentation (fig. 4b). Several different proposals for interpreting the ancient buildings, through the analysis of transformation processes (including both cultural and sedimentological causes) brought to final interpretation of ancient dwelling, now reconstructed at the same scale and with the same plan of the excavation inside the archaeological park of Montale (Cardarelli 2004).

To realize all these operations in the field, we need to operate with resources dedicated to the GIS. It means to have available working station on the field or recording systems (tablets, pads). In such a way the efficiency of the elaboration can add a continuous feed back to the research. In the case of Montale we have worked with three personal computer positioned in a laboratory next to the excavation. For other more difficult conditions we can use mobile stations. This process obviously means the indispensability to have workers dedicated to the use of digital recording.

Recent efforts of many scholars are based upon the experimentation of small devices that can help recording values. New trends regard the extension to record media files (audio, video) to obtain quickly elements for a cognitive process of what documented.

For the collection of finds, it was choosed a grid of 1 m square as sample unit (for sifting and for flotation). Each record counted through standardized pockets was sifted with 0.5 cm sieve and one of ten, passed to flotation. In case of particular situation the whole deposit was flotated to recover seeds or organic material (charcoal, wood, bones).

A particular trend concerns the treatment of finds, especially abundant pottery found in each archaeological layer. On the field, after each item has been washed and inventoried the provenance, it has been marked with a small label printed and applied to the sherd, and photographed to register a first evaluation of typology and dating.

The registration of main significant finds together with the Harris matrix, can establish the correctness of phase identification. Each stratigraphic unit entered in the GIS can be checked in his phase position, through the use of dedicated software[3], allowing in most of the cases to verify the correctness directly on the field, or at least to remove impossible cycles

This system was applied in several archaeological excavations. The main result of these experiences stand in forcing even in unexpected situations to improve the recording systems and in attempting distribution analysis.

In some cases we should extend the meaning of recording not only traditional relations between stratigraphic unit, but also logical or better "topological" relations. The case of the site of HD-6 (Ra's al-Hadd, Sultanate of Oman) is the best example (Cattani 2003). It is a settlement, dated between the end of IVth mill.BC to early centuries of IIIrd mill.BC, composed of an architectural complex with a large platform, surrounded by a stone and mud wall. Inside the enclosure, the space is parcelled in several buidings, divided by open spaces with, in some cases, productive structures (mainly ovens). Each building is shaped with several rooms, communicating each other.

The study of topological relations and their entry in the database allows to extend the analysis of phases attribution and to attempt to propose the logic in the use of space (Cattani, Fiorini 2004). Especially in the case of HD-6 settlement, that belong to the period of development of tribe organization, confirmed by the funerary analysis of contemporaneous cemeteries, the topological study perfectly fits in the process of explanation from the archaeological record. In this case the methodological improvement consists in forcing the archaeologist to find out directly on the terrain these topological relations. With the use of GIS it will be easy to connect through these relations each part of the settlement and to obtain a first evaluation of social and anthropological use of space.

The application of the GIS in HD-6 that is located in a deserted area implied some differences from the previous case of Montale. Despite larger difficulties in operating on the field, the application of the same methodologies convinced us that these improvement bring enormously more results respect traditional recording techniques. In the case of open and large settlement, for the photographic survey it was used a camera fixed to a kite.

Besides the improvements in survey techniques we must declare that most of the results depend from techniques of excavation and methods of collecting finds. Also in HD-6 all the archaeological deposit was sifted, sometimes with very thin sieve of 1mm. The obvious consideration is that GIS cannot be a useful tool if we do not proceed in detailed and careful excavation with sampling techniques adapted to the situation (ratio among variables like time, financial support, kind of archaeological finds).

A recent evaluation of an excavation of a neolithic site, carried out without GIS support (Sammardenchia, Udine, Northern Italy) but analysed with the same techniques after the digitalization of records, suggested that it is important to establish the unit of sampling or recording each item found in the excavation. The results pointed out that sometime is not so helpful to record each find with his coordinates (mainly flint tools and flakes), but to dig faster for small grid units (20 cm square). The amount of finds from sifting is so high that positioned find, even if the excavation was carried out carefully, represent a low percent of the total. The unique possible analysis is therefore through the summarization and selection of finds for each excavation unit of the square grid.

Another question in the use of GIS concerns the organization of documents related to the spatial information. The use of digital devices produce for each research thousand of photographs, that rarely can be associated in a dynamic sense to respective objects. This limitation imposed by common software must be solved, especially if we mean a high content


Fotomosaico
Immagine singola
File di coordinate
N X Y Z
004 13.032 -8.516 -1.225
005 13.164 -8.048 -1.219
006 13.376 -7.024 -1.377
007 12.941 -6.968 -1.376
008 12.057 -7.902 -1.481
009 12.013 -8.438 -1.472
010 13.790 -5.987 -2.867
011 12.968 -5.824 -2.888

Fig. 2a


Montale (Modena, Northern Italy) manual recording on paper printed fotomosaic

Fig. 2b

of information not translated in the database. So far the best experience, but still very limited is to use visualization softwares that allow to make queries or selection. The use of comparison address to this point an important process in evaluation phases, relative chronology and typological occurrences.

Overestimating capability of GIS in recent times brought to negative comments about this technique among several scholars. According to us it depends mainly from the way of selection and attribution of information and it needs to be readdressed with innovative solution based on fuzzyness and open classification. We need to declare logical rules and semantic networks to obtain best selection of information and to proceed in significative spatial analysis. The result of these analysis need to be expressed in visualization to be considered as another source of data.

Landscape reconstruction: transformations of landscape in the Bronze Age in the territory east of Modena

GIS is the best tool in the archaeological process for the reconstruction of ancient landscape. Several steps take part in the scientific process, including Data acquisition, GIS analysis, Simulating processes and Virtual reconstructions.

We want here to bypass both the steps of field research and the storing data into the GIS. Although we have not reached true innovations in this field, we intend to attract the attention on the topics of dimensions and chronology in connection with the capacity in reading, coding and interpreting data.

At the base of this presentation is the combination of scientific process and empirical methodology.

Common to cognitive archaeology is the strength to identify, but even to understand, limits, boundaries, how these were determined by resources exploitation or by peculiar symbolic elements or from hypothetical information exchange systems.

Best relevance of the paper fits in the need for a revisitation of GIS use in ancient landscape analysis.

The application case has a multiple scale of investigations. It regards mainly the area west of Bologna between Reno river on the eastern side and Panaro river as western limit. In a wider perspective we deal with a full regional evaluation of the entire Po plain. In a more detailed investigation this area is restricted to the territory between Samoggia and Panaro rivers, that is mainly the area of the project of the Archaeological Map of Modena, started twenty years ago with fieldwork and digital archaeological maps (Cattani 1997, Cardarelli, Cattani 2000), where the high amount of records collected, allows to test the use of GIS for a simulating process of reconstruction of ancient landscape.

For the restricted area we will propose here a detailed reconstruction of Bronze Age

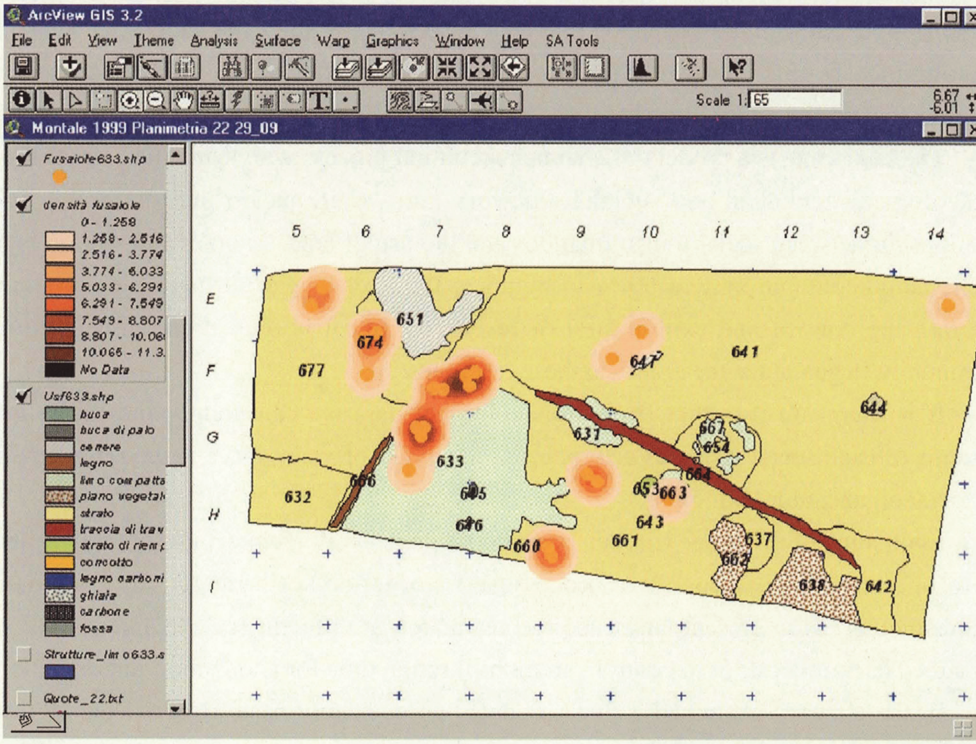

ArcView GIS 3.2
File Edit View Theme Analysis Surface Warp Graphics Window Help SA Tools
Scale 1: 65
Montale 1999 Planimetria 22 29_09
Fusaiole633.shp
densità fusaiole
0 - 1.258
1.258 - 2.516
2.516 - 3.774
3.774 - 5.033
5.033 - 6.291
6.291 - 7.549
7.549 - 8.807
No Data
Usf633.shp
buca
buca di palo
cenere
legno
strato
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Fig. 3a

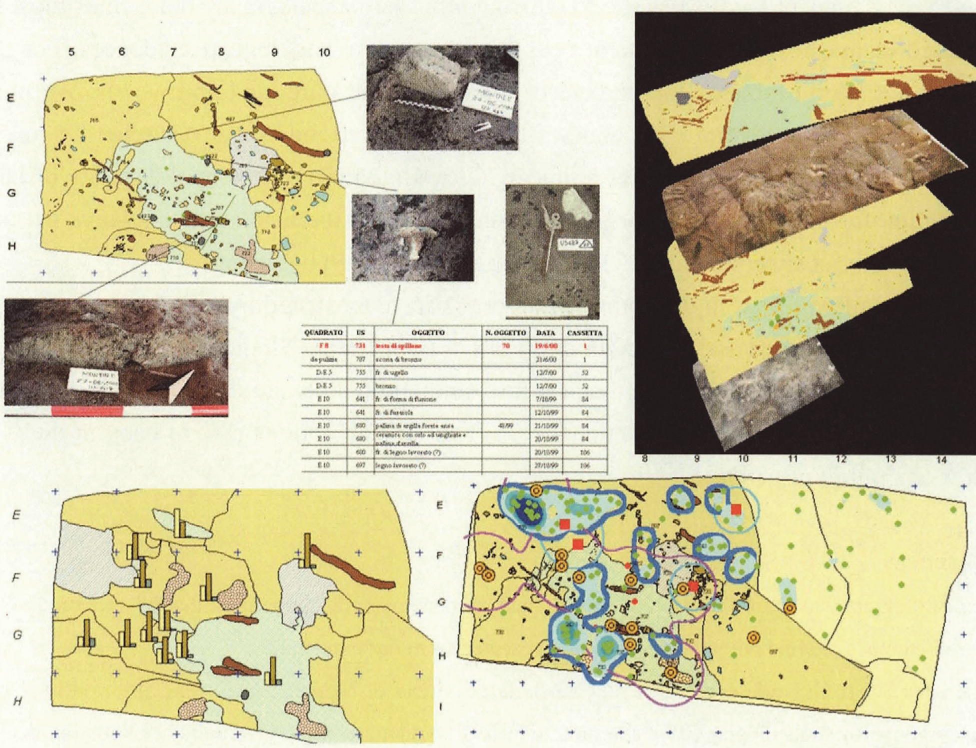
QUADRATO
US
OGGETTO
N. OGGETTO
DATA
CASSETTA

Fig. 3b

settlement pattern with the evaluation of hierarchical position, soil exploitation and suitability, demography. In this reconstruction each step of scientific process was discussed and subordinated to declared parameters.

The landscape is a product of a complex cultural process with symbolic aspects linked to ecological, technical and social framework and we are aware that there is a direct relationship between social transformations and the use of land. Another assumption is that each socio-economic system tends to organize the exchange with natural environment, through the control and exploitation of resources, but it is only the membership to a community to guarantee the access to these resources.

It is therefore true that from archaeological data we can understand the relation systems of each social group as actors. From this point of view, space is the representation of social organization.

Main aims of the paper will be: 1) to propose a network architecture for classification; 2) to outline scientific cognitive processes; 3) to define scale ranges for a validating reconstruction; 4) to present landscape reconstruction at different scale as interpretive step for a feed back process; 5) to control variations through time for a long term interpretation.

In the territory examined a first reconnaissance, mainly base on aerial photographs, survey and excavation a number of small settlements (approx. from 1 to 7 ha) that characterized ancient landscape (fig. 5a). Around this settlements, many other finds must be evaluated or as secondary settlement o as unidentified archaeological evidences. For the territory has been evaluated the percent of arable land, pasture land and woods. We must add as main typologies the river courses banks, usually flooded and occupied by marsh lands. The calculation of amount of surfaces follows the ratio of potential capacity of land exploitation for agriculture and for pasture. This rate fit in the land surface relative to each settlement (obviously contemporary) found out with Thiessen polygons.

The production of high quality photorealistic reconstruction of ancient landscape through the combinated use of ArcGIS and VNS (Visual Nature Studio) software (fig. 5b)

Next step will concern the attempt to use simulation software developed on case base reasoning or agent-based social simulations. All these elaborations can go back in the GIS addressing future research.

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Note: Bibliography used for this paper is so huge and so many were the quotations, that we preferred to list only references to find out widening of what presented from our experience.

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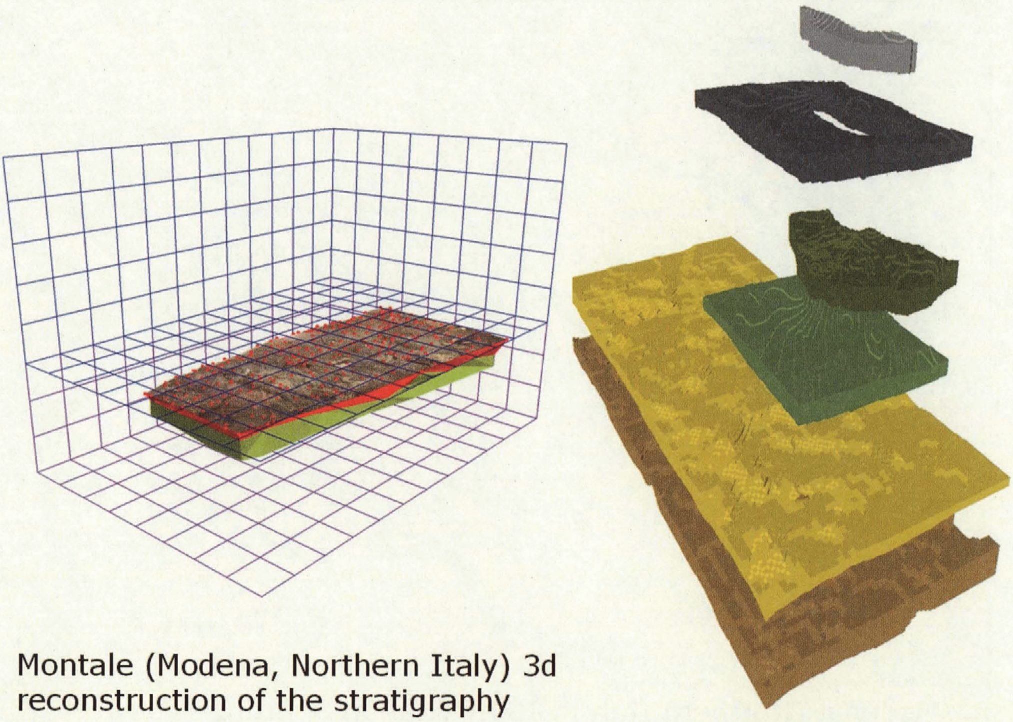

Montale (Modena, Northern Italy) 3d
reconstruction of the stratigraphy

Fig. 4a

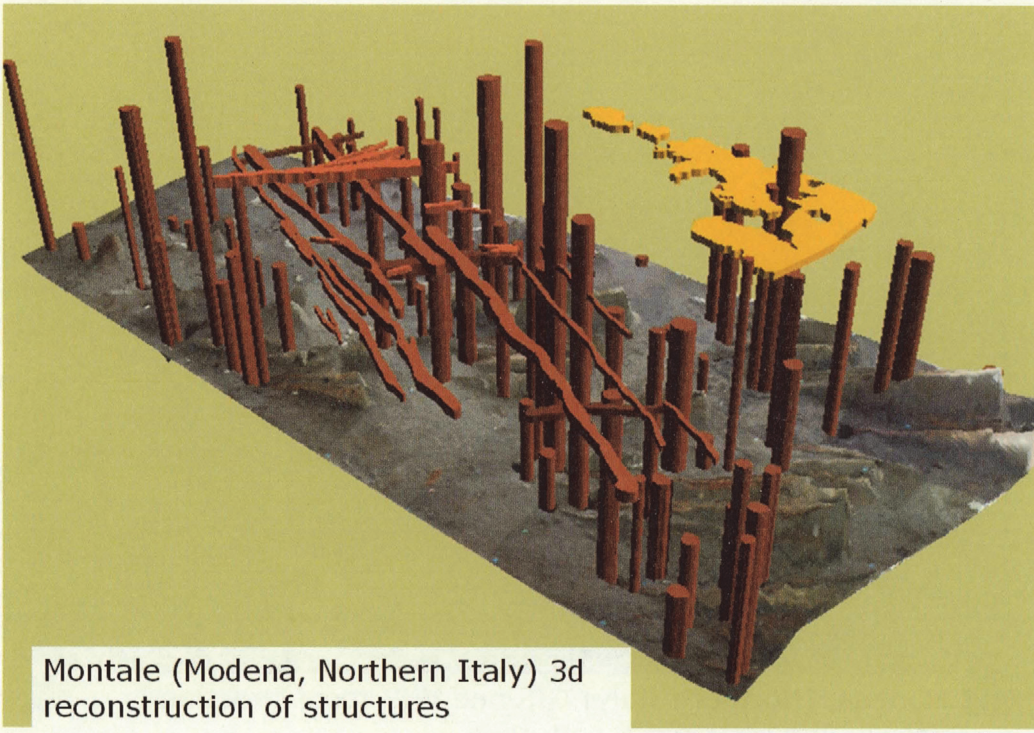
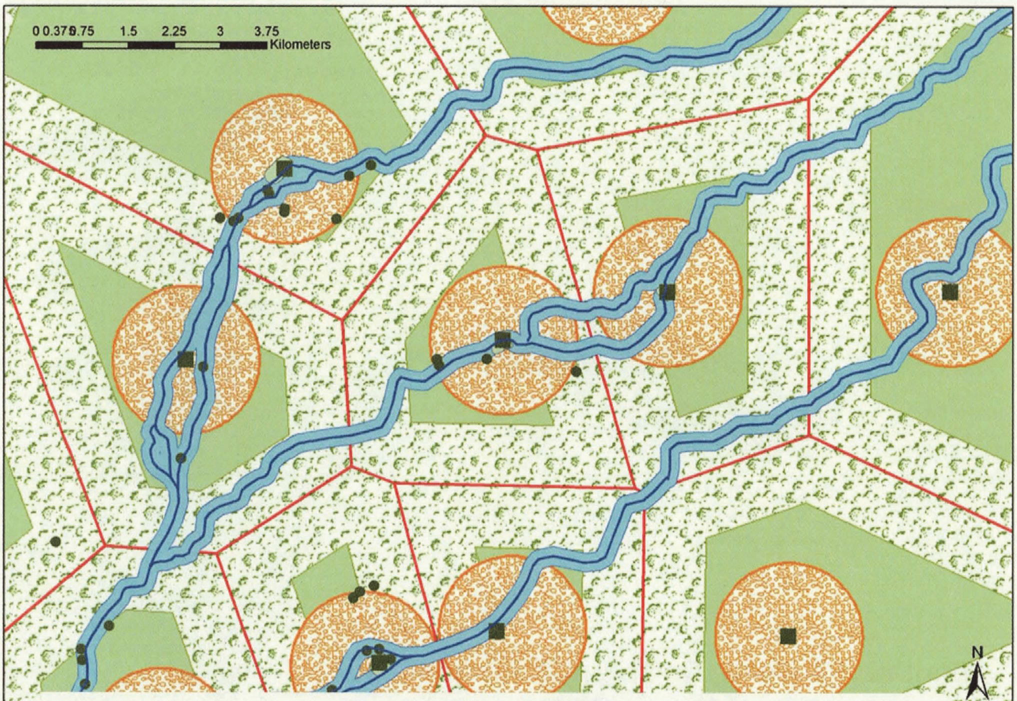
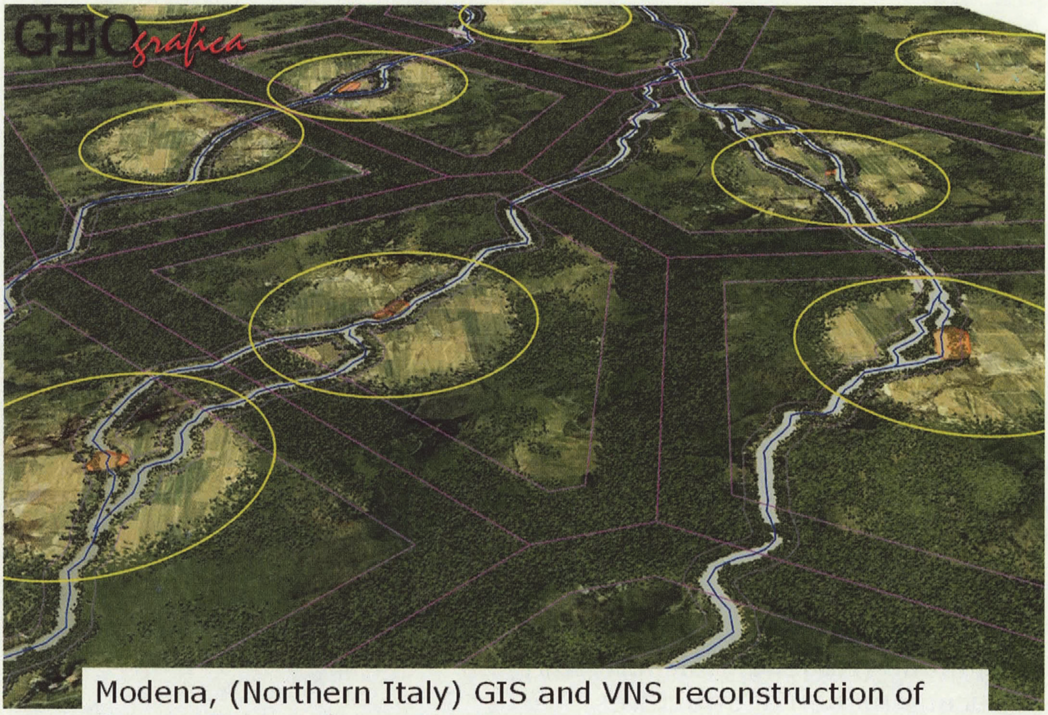

Montale (Modena, Northern Italy) 3d
reconstruction of structures

Fig. 4b



Modena, (Northern Italy) GIS evaluation of Bronze Age settlement pattern

Fig. 5a



Modena, (Northern Italy) GIS and VNS reconstruction of Bronze Age settlement pattern

Fig. 5b

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Notes

1 MSR (Metric Single Image Rectification) della Rollei (www.rolleimetric.de), digital photogrammetric system for the two-dimensional evaluation of plane objects. The perspective photo is transformed into a parallel projection with the aid of known object information, e.g. control points or nets of distances. The accuracy of the parameter determination for the projective transformation and thereby of the rectification depends on the following parameters: flatness of the recorded object; camera angle to the object; camera angle between image plane and object plane does not just influence the visibility of the object, but also the allocation of the object information; camera system's optical recording function, correction of the distortion; resolution of the digital image, higher accuracy for the rectification can be expected with increasing; image resolution, because the allocation of image and object co-ordinates is more precise. The most favourable photo configuration for true to scale photogrammetry would be something that comes close to parallelity of object and image plane (plan view) and that has a surrounding control point field (MSR online help).

2 Arcmap, ESRI

3 Arched

GISを利用した考古学研究に対する期待、評価および可能性

マウリッツィオ・カッターニ

ボローニャ大学

おおよそ10年前、考古学研究における多くの疑問は不問に付されていた。大部分の考古学者は「ニューアーケオロジーの実験」の精神を失い、彼ら自身が何を発見していたのかを認識する過程を急激に喪失していた。現在、われわれはGISを利用できる環境にあり、多くの問題の解決の入り口にいるようにも思えるが、実際の考古学的な記録を管理することに注目すれば、GISへの過剰な期待であることも否定できない。この論文では、最近のGISの適用事例を通じて、考古学情報を管理する際のGISの基本的なアセスメントと性能について議論したい。このシステムは、精度の高い多くの情報を分析することのできる強力なツールである。GISがデータを変換したり増やしたりできるだけでなく、考古学者がフィールド調査を通じて、より対象の時空間的なコンテクストに対して配慮し、そうした情報を探索することを惹起する意味でも、このシステムは考古学研究にとって革命的なツールであると考えることができる。

フィールド調査における適用については、

— 発掘の際における３次元的なミクロ層位学（Microstratigraphy）

— 認知考古学のための位相表現

— 復原した空間情報の表示

— 景観復原

などを考えることができるだろう。デジタルデータだけでなく、より多くの情報を発見する方法などについての概念的な刷新や日々の適用研究は常に進められている。新しい解法や方法を確立するだけでなく、考古学研究における日々の実践を強く意識しなくてはならない。

多くの事例は、集落発掘などの研究でトレースすることは可能だが、景観の評価と復原においては、我々は冒頭の視点を拡大することができる。こうした適用研究の基礎には２つの基本的な想定が存在する。それは、よりよいドキュメント化を必要とすることと、調査後できるだけ早い段階で対象の再構築と解釈に立ち向かわなくてはならない、ということである。これを現実化できるのは、デジタル化された考古学情報だけである。膨大な量のデータ、写真、数量化された出土品のリストなどの資料化について、フィールド研究の期間に取り扱うことができる。さらに空間統計学的な分析手法は、研究継続の方法や方向性すらも予測的に検討することを可能とする。

（和訳：津村宏臣）