

A GIS PLATFORM DEDICATED TO THE PRODUCTION OF MODELS OF DISTRIBUTION OF ARCHAEO(ZOO)LOGICAL REMAINS.

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ABSTRACT

The paper considers all the problems related to the planning of a digital tool for processing faunal remains with the use of a GIS (Geographic Information System) solution.

Archaeological data processing can be done on different levels: it can concern both the production of thematic maps or the elaboration of interpretative and predictive models, using statistical and mathematical tools.

The distinction between an excavation and an animal bones analysis GIS platform is based on differences in data processing methods. In fact the detail level shifts from stratigraphical contexts to the set of bone fragments pertaining to the same context (or structure, or period, etc.); at the same time the underlying database (strictly dialoguing with the GIS platform) becomes our animal bones DBMS instead of the excavation DBMS.

Data frequency (and eventually other statistical analysis) are done on the DBMS and then imported within the GIS platform as points related to the zooarchaeological sample; using a GIS technique called geocoding, coordinates of the points are generically positioned inside the stratigraphical context they belong to.

Our aim is to display the bone deposit, by using stratigraphical and zooarchaeological keywords in order to understand how anthropic, animal and natural factors transformed the original animal population into a fossilized sample.

Experimenting of GIS technology on a large open area excavation like the Poggio Imperiale project (more than 1.5 hectares excavated, with a bone sample of 5.763 fragments), has allowed us to produce important information used in elaborating diachronical models of social and economical structures; it is also possible to predict the archaeozoological potential of non-excavated areas, through a combination of statistical and spatial analysis.

Keywords

Archaeozoology, Taphonomy, Geographic Information System, Faunal remains, Medieval Archaeology, Computer applications in Archaeology, Quantitative methods.

1 – The creation of a new recording system: integrating the archaeozoological discipline

For over 20 years, archaeozoologists have been complaining about a lack of integration between our discipline and archaeological research: collecting and studying animal bones should not be intended as a complementary activity within an excavation's strategy. Notwithstanding this, it still usually happens that osteological finds are handed over to specialists only when archaeological projects are in an advanced phase, or when the excavations are finished. Nowadays, an archaeological research project should provide an interdisciplinary approach from its very first step, and zooarchaeology should be among the considered disciplines. The absence of a comprehensive planning often generates gaps that are hardly recovered. If the specialist is extraneous to the questions derived from an excavation, the animal bones lack of an adequate contextualization; this usually brings to a loss of information.

The creation of an integrated system for the management of archaeological data (Valenti 1998; Francovich 1999) at the LIAAM (Laboratory of Information Technology Applied to Medieval Archaeology), moves exactly from the need of narrowing the distance between the main discipline and its subsidiary sciences. The system is structured on several GIS platforms (regarding GIS

solutions for archaeological excavations see Valenti 2000 and Nardini 2000) completed by appropriate databases (Valenti 2000; Fronza 2000).

Having access to an information system containing all data produced by a project allows the specialist to put the osteological finds within their context, avoiding all those slow and complex operations that often arise in the case of a poor collaboration on the field. In other words, it ensures a better quality of work and a drastic reduction of retrieval/processing times and of errors in reading archaeological data.

In a GIS platform the researcher is able to practice a real time observation of the finds within their spatial and chronological collocation (figures 1-6). The usefulness of such a tool is particularly clear in the case of open area and multilayered excavations, where the finds have different distribution modalities in the horizontal deposit. A good example comes from Tel Qiri, an Iron Age settlement in Israel investigated by Simon Davis, where osteological and anatomical distribution of finds in five different ritual areas has shown a difference in cultural practices: in the period 12th-8th century b.C. the sacrifices regarded almost exclusively right forequarters of goat-sheep, and in particular of lambs and kids (Davis 1987).

The experimentation of GIS platforms in the production of animal bones distribution models, points at the creation of a tool useful in visualizing information derived from a synchronic analysis of bone deposits, and particularly of its spatial layout changes on the basis of different criteria (taxonomical, osteological, etc.).

Archaeozoologists can therefore interact with the platform by formulating questions and combining osteological and archaeological data in order to confirm, widen or deny the hypothesis made on the samples. In fact they are involved in the excavation questions even if they have not directly participated to the campaigns; this allows an easier approach to the interpretative grids of particular sites and a deeper contribution of elements that integrate and complete the archaeological understanding of a settlement, for example by pointing out specific functional or productive areas or the presence of social stratifications.

A digital data management allows also to use the same recording system for all information collected on the field or produced at the laboratories: this ensures a perceivable improvement in work methodologies and the real possibility of generating distributive charts; retrieval and data management times are heavily reduced. This is a way for archaeozoological research to stop being an accessory discipline and start growing into a part of a complete “archaeological container”; it becomes an integrating element of archaeological research, considered in the data model structure as well as in the data processing phase.

The attempt to extend the GIS solution to the spatial reading of finds (pottery, metals, osteological finds, glasses) points at the characterisation of variables that ensure more detail in calibrating the historical models produced by archaeological researches. In the case of animal bones, the possibility of a spatial visualization of osteological deposits can supply useful information, especially in the understanding of alimentary customs, economical activities, cultural practices and social organization; this clearly implies that different spatial distribution derive from the listed issues.

In other words it is a redefinition and application of the schleep effect, which takes into account new variables in respect to those previously considered for pre- and protohistorical contexts; the more articulated complexity of historical age economical systems, the social structure of human communities and the development of communication means and ways become important factors in the interpretation of eventual anomalies in anatomical concentrations (and not only in them) of species recovered in different parts of a settlement.

Statistical analysis on bone deposits has been put forth when the amount of data recorded in the DBMS *Scavo Archeologico* (archaeological excavation) and the architecture of the Poggio Imperiale’s excavation GIS platform have reached an optimal integration degree, which could allow to translate data into information. Once the system planning and data entry phases have been completed, the GIS platform has been used to produce information, based on an “intelligent” use of digital tools.

This means that our GIS solution uses the DBMS *Reperti Osteologici Animali* (animal bones DBMS; see the paper by Boscato, Fronza and Salvadori in this volume) to obtain frequency analysis and the GIS platform to visualize the results in space; both are necessary, since the single bone fragment is not recorded as an autonomous graphical object within the GIS platform, but can be represented through an integration of the alphanumerical (DBMS) and geographical (GIS) databases.

In fact, data related to the osteological sample are imported within the GIS platform as point objects directly derived from the frequency analysis put forth on the alphanumerical database; the choice of using a point shape is due to the fact that finds do not have real spatial coordinates within the GIS: the corresponding *X* and the *Y* values are conventionally placed within the space occupied by the stratigraphical unit they come from (the modalities of digital data processing are described later in this paper).

The situation represented with the use of a computer is by no means different than the real one; on large open area excavations the spatial placement of finds within their context is hardly ever recorded. Whoever tries to georeference finds after the end of an excavation or considers a work poor if it is not based on graphical objects that represent the real fragment, supports a methodological issue that does not correspond to reality: archaeologists collect finds coming from earth moved by excavation practices that upset the original horizontal deposit.

This doesn't influence the fact that in some cases the position of finds within stratigraphical contexts can be an extremely important element in the comprehension of a deposit. If a similar situation occurs, finds will be drawn and georeferenced through overlays of plans; it will then be possible to digitalise the finds within the GIS, just as it happens with the stones of a wall or the bones of a skeleton.

Therefore, the method we adopted for Poggio Imperiale does not derive from intrinsic limits connected to the excavation records or the digital management, but has to be considered as a conscious operative choice. Moreover, this type of sample analysis is based on frequencies instead of on single drawn and georeferenced finds; in other words we could call it an "areal" rather than a "punctual" solution. It points at a recording procedure related to typological classification of finds, trying to override an examination of the single bone in order to privilege a global comprehension of the population; such an approach aims at the production of thematic models that explain the formation dynamics, which do not rely on punctual reference at a single fragment detail level.

On the other hand, "punctual" analysis is more appropriate in the case of prehistoric contexts or of particular situations (burials or heavy find concentrations); in these cases excavation times become longer since each single find is preliminarily catalogued and drawn on the context's overlay. The fragment can be identified with an inventory number and directly recorded within the database on the field; the data can then be completed during the exhaustive laboratory analysis. Such a strategy produces valid information for thaphonomical investigation and for the comprehension of natural processes that determined the osteological finds deposition.

This type of solution has been experimented on the excavation taking place under the Cathedral of Siena, conducted by the Area of Medieval Archaeology of Siena University (Causarano M., Francovich R., Valenti M., 2003). The discovering of three dog depositions dating to roman imperial age, forced us to produce detailed plans of every single anatomical element in the context (figure 7), assigning inventory numbers to identify the finds on the drawings as well as on the bags that contained them; in this way it has been possible to integrate alphanumerical and graphical databases.

Another example of "punctual" analysis has been conducted on the excavation of Nortarchirico (Basilicata, Italy), a site dating to the medium-initial Pleistocene (Tagliacozzo *et al.* 1999); in this case the archaeozoological intervention regarded finds located in the fill of a dried-out paleoriver-bed and aimed at understanding the processes that determined the deposit's formation. A graphical reproduction of the evidence has been done; resulting into a georeferenced map representing every single bone fragment within a grid based on taxonomical and anatomical

identification, orientation, length indexes and surface alteration grades. The spatial reading that followed has been focused on a frequency analysis based on the paleosurface's excavation grid and different combinations of classification attributes.

Since the deposit is made of sediments derived by water activities the results returned thaphonomical indications; in other words a preferential orientation of finds points to the flow direction, the presence or absence of specific anatomical elements shows their transportability grade, the preservation of the bone surface is related to the alterations operated by water.

The thematic maps published in the volume represent the fragment's position and the different taxonomical classes that have been recognized (elephant, fallow deer, ox). On the other hand, the frequency analysis is represented through a coloured grid where different excavation squares assume variable chromatic themes on the basis of the observed values. It is not clear if the analysis derive from a digital application (no reference about it appears in the publication); it is anyway true that a similar information could easily be treated within a GIS platform like the one developed for the Poggio Imperiale project.

The excavations at Isernia la Pineta (Anconetani *et al.* 1996) propose a different experience; in this case the researchers implemented a specific digital application to manage animal bones. It is made of a database supported by a graphical base representing the paleosurfaces (a doubt remains about the application of a CAD rather than a GIS). The authors claim that this solution allows graphical representation of finds on a generic digital platform as points or real figures; these are defined through a set of coordinates stored within a database and a shape also derived from a database containing standard objects of stylized osteological segments codified in a geometric lexicon. The spatial analysis on the dataset should return useful information on fragmentation typologies in order to understand anthropic bone crushing techniques.

In conclusion, these cases prove that a digital management solution has to be calibrated on the specific needs of an excavation: it would not make sense to establish aprioristic criteria to judge the validity of a developed tool.

Obviously, if the excavation finalities request a "punctual" registration of finds within the stratigraphical sequence (as in the examples we have discussed above), the exact position will be taken on the field and then recorded on a digital system through real coordinates; in the case of contexts where the material is better monitored through frequency and distribution analysis (without a relevance of the exact location), the method adopted at Poggio Imperiale perfectly fits complex research needs.

Moreover, the application of distributive models on a GIS platform is by no means influenced by the two different recording systems; the solution we are here presenting can easily be adapted to both methodologies. The only difference lays in the data entry phase. In the case of "punctual" recordings the finds have to be digitalised following the overlays, just as it happens with the single georeferenced stratigraphical units; quantitative analysis will be made directly on the GIS or through the use of an external database. Our DBMS *Reperti osteologici animali* (animal bones DBMS) has a module on the single find's location, allowing the recording of X, Y and Z coordinates; these fields allow to preserve within the database the real coordinates of the find's deposition in order to visualize it as a generic georeferenced point by simply exporting them to the GIS platform. Therefore, if particular excavation contexts require an exact recording of bone positions it will be sufficient to record the coordinates on the field and enter them into the database; in this way we obtain an authentic reproduction of the deposit within the GIS platform, except for the exact shape of the find.

2 – The GIS platform : a tool for the development of distributive models of finds

To implement distributive models of finds we used a software extensions of MacMap (the GIS application we adopted on the excavation of Poggio Imperiale in Poggibonsi, near Siena); in fact the "Localization" feature allows to represent as points the alphanumeric information of a tab-

separated text. Coordinates of each point are derived from the centroid of the object used as “localizer”. This method has been tested on animal bones and will be soon applied also to other classes of finds (pottery, glass and metal finds); in the case we are presenting here the localizer has been the stratigraphical context, so that the point is located exactly in the middle of the relative SU shape.

The generated symbol takes from the alphanumeric database all the data we need, storing them in previously created fields of the GIS’s platform’s internal table. A tab-separated text file concatenating the SU number, the excavated structure, the animal species and the number of fragments (an example of text row could be “366/C3/ox/3”) is automatically represented as a point located at the centre of the stratigraphical unit 366, and the appropriate fields are filled with the following values: structure=C3, species=ox, number of fragments=3.

This data import operation can be done at any time and regard all the frequency criteria needed in the analysis of a specific population. There are no limits in the creation of the tab-separated text file since the GIS base is easily adaptable; the only thing it requires is that the necessary fields are defined within the internal table. The platform’s flexibility allows to test different options related to the detail level of the import process; it is possible to import all the records from the database by establishing a “point to single record” correspondence, or the results of a frequency analysis by setting up a “point to single frequency value” correspondence.

There is no need to adopt a specific data model; the addition of one or more point types to the normal excavation architecture suffices all the requirements of the analysis. Data is directly stored within the GIS base, and deleted after its reading in order to avoid useless growth in heaviness of the platform.

Until now, two point types have been added to the excavation base, representing different distributive analysis. The first stores frequency values related to species found in the single stratigraphical units (or, indifferently, in the single excavated structures); the second regards a distribution of anatomical elements of a species within each excavated structures. Distribution by species, regardless which the adopted stratigraphical parameters are (SU, excavated structure, phase, etc.), is usually the first evaluation of an osteological sample; the second type allows a more in depth analysis of anatomical elements referred to the taxonomical category they pertain to.

As we have already noticed, the need of keeping separated types for different evaluations does not depend by the GIS platform but lies on the choice of correctly organizing the acquired knowledge. Fields for the SU number, the excavated structure and the species are common to both types; the first one is completed by a single field containing the number of fragments, while the second has a number of coupled fields that contain the single anatomical parts with the relative frequency value.

After data import has been completed, several thematic maps (called views) are created by taking advantage of MacMap’s visualization features; these range from simple coloured points, to pie charts or dimensional icons (objects changing their size on the basis of the percentage value they represent).

Global distribution maps can also be produced, showing the areas of maximum concentration through concentric circles with different chromatic values based on the evaluation’s results; another effective visualization is obtained by a colour gradation of single stratigraphical contexts (SU) in proportion to the percentage values of find’s presence.

The goal of this operations is to produce distributive maps where excavation plans, organized on the specific needs (as period or phase plans, excavated structures plans, etc.), are completed by symbols that express the results of frequency analysis previously processed through the use of the DBMS *Reperti osteologici animali* (animal bones DBMS). It is therefore possible to translate the effects of our investigations into a comprehensible and easily readable representation system and, overall, to achieve a real integration of archaeological and zooarchaeological data sources.

3- Specification of frequency analysis parameters

More than once in this paper we underlined the choice of graphically represent processed information on a georeferenced platform. Frequency analysis are based on specific stratigraphical and archaeozoological criteria, and performed within the animal bones DBMS (see Boscato, Fronza, Salvadori in this volume); the role of the GIS platform consists therefore in visualising and spatially localising the outcomes of the database.

Dispersion of bones in space is, as we know, a sum of anthropic, animal and natural factors; it is the result of a long process, which transforms the original living population into fossilized samples. To study the spatial distribution of the finds recovered on excavations, means trying to understand how and in which way these factors have influenced the deposit.

The use of a GIS platform as an analysis tool can be extremely useful in understanding these issues. All aspects derived from find cataloguing are directly involved; frequency analysis, obtained through combination of fields that are part of the animal bones DBMS and data previously produced by archaeological investigations, are directly viewed on the GIS. In fact all quantitative data can potentially be transferred to the platform and provide evidence that allows significant advances in dynamic readings of a deposit.

In the case of Poggio Imperiale, the development of a GIS solution focusing also on zoological finds has been aiming at the comprehension of socio-economical models of the settlement. This is why we used the database to obtain a concentration of species attested in the excavated structures belonging to the same chronological phase, subsequently visualised on the GIS platform (figures 1-6). The presence or absence of some species within the buildings are taken as an evidence of differentiated meat consumes, and eventually of social stratifications. The same methodological rule is applied to the distribution of anatomical elements pertaining to the same taxonomical class: a higher or lower presence of particular elements, again within different structures, could point at a qualitative distinction of the inhabitant's diet. Moreover, the distribution of finds allows to derive information on the activities carried out in the buildings: in the case of a high number of discarded bones (such as limb's extremities or cranial, costal and vertebral remains) in comparison to long bones, it can be possible to advance the hypothesis of slaughtering activities; if, on the other hand, their number should be very small we can imagine a residential function of the building.

Age of death is another parameter that can yield interesting evidence of social differences: structures that preserve homogeneous populations in terms of age can be interpreted on the basis of meat quality, which will obviously be higher in the case of young animals.

The examples we have seen clearly show how the visualisation potentialities of the platform allow a real time and exhaustive comparison between synchronic samples, processed by the researcher through the use of the DBMS, on the basis of stratigraphical and zoological criteria

While the DBMS has been planned to store zooarchaeological data independently of a site's specific issues, the GIS solution has been focused on the Poggio Imperiale excavation, where the deposit's nature and the archaeological interpretative grids have allowed an almost perfect data integration. This means that the GIS platforms applied to archaeozoological analysis have to be calibrated on different research needs directly derived from the preservation state of the deposits.

4 – First results and new research perspectives

We present here a limited example of the results obtained by data treatment applied to the Carolingian age phase of the Poggio Imperiale excavation, where this solution has been experimented for the first time.

The settlement of this period has returned a fairly large osteological sample (1.072 bone fragments). It is a village of wooden huts articulated around a longhouse (called Capanna/Hut 3); in this case we have considered the four structures (huts 1, 7 and 10, figure 1) that lay closest to the main building. Analysis of the osteological deposit has therefore been aimed at a comparison between the samples pertaining to the floor contexts of the four structures, in order to isolate anomalies that could derive from economical, social and alimentary factors.

The stratigraphical parameter we adopted has been the single excavated structure, that means all the stratigraphical units pertaining to the same hut; the choice of zooarchaeological criteria (selected, as we have already said, on the *DBMS Reperti osteologici animali*) was based on five different research issues:

1. the first quantitative operation regarded a general evaluation of deposits within the four structures (identified and unidentified fragments), using a pie chart as visualization method on the GIS platform (figure 1);
2. secondly we explored the distribution of species, using a dimensional visualization where the size of graphical element representing the species depends proportionally on the frequency value (figure 2);
3. the third operation interested each single species, by calculating its numerical consistence within each structure (figure 3; visualization method has been, this time, a colour gradient);
4. the bone fragments have finally been compared by estimated age of death, grouped in four classes: 6-12 months, 12-24 months, 24-36 months and generic adult; the output has been based again on a colour gradient. This operation has shown a clear prevalence of anatomical elements within the Capanna/Hut 3, especially in the case of the age groups 24-36 months (figure 4) and generic adult (figure 5); the difference with the other structures is absolutely relevant.
5. a last comparison has been based on the distribution of ox fragments by anatomical elements, considering only the long bones; the results have been visualised through a pie chart (figure 6); they show an absence of bones in Capanna/hut 1 where only a few fragments pertaining to the limb's extremities have been found, a high incidence of radio-ulna in hut 10 and a dominance of humerus and tibia in hut 3.

The evidence of a hierarchical character of the settlement, already stated on topographical basis (the central and articulated longhouse surrounded by smaller huts), seems plainly confirmed by archaeozoological data.

The model that we can derive from the finds distribution, with a particular reference to ox remains, is based on an alimentary hierarchy. The consume of higher quality bovine meat (anatomical parts and age of death) can be seen as a distinctive element related to the inhabitants of the longhouse Capanna/Hut 3.

The results obtained at Poggio Imperiale make it clear that the structuring of a GIS solution lies especially on a research's finalities, on the knowledge of the software's features and, subsequently, on the development of a suitable tool. The creation of an open management system can not be done without a clear solution planning based on a single context evaluation.

An important step in this direction, has been the characterisation of the two processing methods ("punctual" and "areal"), which represent the main recording techniques adopted on excavations and are directly connected with the research strategies.

Potentialities related to similar analysis can also involve the thaphonomical aspects that determine a sample's deposition; especially for what concerns anthropic activities, it is possible to distinguish four research fields aiming at the production of socio-economical models of past societies:

- A. economical model (visualisation of distributive plans based on a settlement's chronological phases)
 - distribution of species
 - distribution of anatomical elements referred to the same taxa
 - distribution of ages for each species
 - find concentrations
- B. social distinctions (visualisation of concentrations in each structure)
 - distribution of species
 - distribution of anatomical elements referred to the same taxa
 - distribution of ages for each species
 - fragmentation typology, referred or not to the species

- C. activities related to the structure's function (visualisation of concentrations in each structure)
 - distribution of anatomical elements referred or not to the same taxa
 - fragmentation typology, referred or not to the species and the anatomical element
- D. specialization of internal areas or rooms of a structure (visualisation of concentrations in excavation squares)
 - find concentrations
 - distribution of anatomical elements

These four subjects can be developed, following different research interests, through a combination of archaeological and zoological parameters; such a procedure is rarely applied, but turns out to be quite effective in a historical research perspective.

This paper has not to be intended as a criticism towards the traditional methods of zooarchaeological investigation; in the last years quantitative and statistical analysis have played an important role in understanding of a faunal population. The real enhancement is, on the other hand, related to potentialities of graphical visualisation and automatic processing, which drastically reduce data treatment times and result into a higher intelligibility of a sample's spatial distribution. Archaeozoological research has expressed itself, until now, mainly through tables and charts representing frequency values based on the detail level of the laboratory analysis conducted on the sample. It is, at least, doubtless that the readability of similar outputs is quite complex, especially because references to the stratigraphical context are often unclear.

In conclusion, to manage frequency distributions on a GIS platform means gaining in immediacy of data fruition which is reflected in a better comprehension of an osteological sample as well as of the factors that determined its fossilisation. Following in this direction will lead, we hope, towards an improvement in integration between archaeological and archaeozoological research, as has been often looked for in the past twenty years.

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Figures captions

Figure 1 – Poggio Imperiale in Poggibonsi (Siena, Italy), GIS platform. PERIOD X (*second half 9th – beginning of 10th century*): pie chart view of identifiable and unidentifiable fragments for each structure.

Figure 2 – Poggio Imperiale in Poggibonsi (Siena, Italy), GIS platform. PERIOD X (*second half 9th – beginning of 10th century*): proportional view of fragment per species for each structure.

Figure 3 – Poggio Imperiale in Poggibonsi (Siena, Italy), GIS platform. PERIOD X (*second half 9th – beginning of 10th century*): colour gradient view of ox fragments for each structure.

Figure 4 – Poggio Imperiale in Poggibonsi (Siena, Italy), GIS platform. PERIOD X (*second half 9th – beginning of 10th century*): colour gradient view of ox fragments for each structure, limited to the 24-36 months age range.

Figure 5 – Poggio Imperiale in Poggibonsi (Siena, Italy), GIS platform. PERIOD X (*second half 9th – beginning of 10th century*): colour gradient view of ox fragments for each structure, limited to the generic adult age range.

Figure 6 – Poggio Imperiale in Poggibonsi (Siena, Italy), GIS platform. PERIOD X (*second half 9th – beginning of 10th century*): pie chart view referred to diagnostic zones of ox fragments for each structure.

Figure 7 – Cathedral of Siena (Italy), GIS platform. Graphical plan of dogs deposition where different colours represent the anatomical elements.