PROPOSAL OF A FAUNAL REMAINS DATABASE

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Summary
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The paper considers all the problems related to the planning of a computerised tool for archiving and processing faunal remains. We present a database management system used by the Prehistorical Section and by the Medieval Archaeology Area of the Archaeology and Art History Department and by the Prehistoric Ecology section of the Environmental Sciences Department of the University of Siena. The solution, open and flexible, has been created after the experience of the LIAAM (Laboratory of Information Technology Applied to Medieval Archaeology; http://archeologiamedievale.unisi.it). Evolution of the database since 1996, detailed description of its functionalities and possibilities connected with the use of it are dealt under an archaeozoological perspective. The paper faces also aspects related to information technology, such as data architecture, normalization of language, programming of user interfaces and automation utilities.
In conclusion, the DBMS we are proposing has proved to be efficient in the practice of archaeozoological research; digital recording reduces the occurrence of errors during data entry, allows comparison between different contexts and, above all, it provides powerful tools for real time processing of one or more samples.

Keywords
Archaeozoology, database management system, Medieval Archaeology.

1 - The DBMS *Reperti osteologici animali* (*Animal bones* DBMS): basic problems in planning a solution

The database system we are presenting was conceived at the LIAAM (Laboratory of Information Technology Applied to Medieval Archaeology, http://medievalarchaeology.unisi.it), a structure of the Siennese University's Archaeology Department (regarding the LIAAM's activities see Valenti 1998; Francovich 1999; Valenti 2000; Valenti *et al.* 2001). It was initially developed to store and manage the faunal remains of the excavation of Poggio Imperiale (Poggibonsi- prov. of Siena), a pilot project of our Laboratory.
The planning and development of this tool is the result of a continuous and fruitful effort, put forth by a team of specialists belonging to different disciplines: archaeologists, zooarchaeologists, palaeontologists and database developers (Boscato *et al.* 2000). This is particularly evident in the authors of this paper: Paolo Boscato has been the scientific supervisor of the project and has always brought new stimulating ideas, Vittorio Fronza has been engaged in all the IT aspects and especially in adapting database management technology to ongoing archaeological and zooarchaeological research; finally, Frank Salvadori has acted as the connection ring between database management and zooarchaeological research by experimenting for more than 5 years the real functionalities of the system on the analysis of bone samples.
Some basic assumptions adopted in the development of a digital solution at the LIAAM represent an essential introduction to our work. Planning a database that has to suit the large amount of data produced by an archaeological project means developing a tool for knowledge production. Such a goal is not always easily achieved; the use of computers often reveals new

research claims and needs, starting a progressive creation process of different toolsets. This applies also to the excavation DBMS (database management system), and particularly to the part concerning animal bones; a constant impulse to improve the available features has been the engine of a feedback process on data architecture, which has brought to a progressive step-up in managing research potentialities (fig. 1).

The DBMS *Reperti osteologici animali* (animal bones DBMS), implemented in a FileMaker Pro environment and part of a larger excavation database, represents therefore an open and flexible tool, to be continuously updated in order to meet new research directions or to manage more information classes. The actual version can be considered as the third release of the system (fig. 3).

The first product was planned in winter 1996-1997 and implemented as a simple and linear database on zooarchaeological records; an upward relation within a hierarchical tree ensured linking to excavation contexts. The relation between the table *Ossa animali* (animal bones) and the table *Unita stratigrafiche* (Stratigraphic Units) was maintained through a key-field (or identifier) built on a string containing reference to excavation area and number of the stratigraphical unit. Starting with this first release, the user interface has been planned to be intuitive and make data entry easy for specialists who were accustomed to paper record sheets: all data concurring to form the record of a single bone appeared on the screen. In planning the DBMS, representation of osteometric turned out to be quite complex: the solution we adopted provided a number of fields corresponding to the maximum possible amount of measures on a single anatomical element, that means 50 fields matching the measures suggested by Angela Von den Driesch for the cranium of several species (Von den Driesch 1976). Each field had a numeric label, which had different osteometric meanings for each species and anatomical element; field n° 1, for example, corresponded to the bone's greatest length (GL) in the case of a record regarding an ox's metacarpus, while the same field in a record of a pig's molar tooth represented its occlusal length.

In extending the use of the database developed for Poggio Imperiale to all the excavations of the Medieval Archaeology Area of our Department, considerable changes were applied to the data model; these affected especially the key-field for the relationship with the stratigraphic contexts database (a string identifying the excavation project was added to the previous key made up by excavation area and context number) and the management of osteometric measures. The DBMS *Reperti osteologici animali* (animal bones DBMS) changed into a relational system based on a hierarchical structure linked upwards (with the SU database as before) and downwards (with a new table called *Misure*-measures). Osteometric data were therefore separated from the *Ossa animali* (animal bones) archive, and stored in a separate table (becoming in fact a module of the system); data entry of the measures has been made possible directly from the main table, through a portal (a sort of window within the *Ossa animali*-animal bones table, showing data from the related *Misure*-measures table) containing two fields: *N° Misura* (measure n°) and *Valore* (value) (fig. 4).

The third and last major upgrade has been completed towards the end of 2000, and involved important changes on data structure (fig. 2), the elaboration of specific vocabularies and *thesauri* to normalize data entry and avoid errors, the development of statistical features. This release represents a standardized tool in recording and processing zooarchaeological data; it is now adopted by all projects of the Medieval Archaeology Area (the database has been tested on the excavations of Poggio Imperiale in Poggibonsi, Campiglia Marittima- prov. of Livorno, S. Maria del Carmine monastery in Siena and is actually being used to store data from the excavations of Rocca di Selvena-prov. of Grosseto, Cathedral of Siena, Castle of Miranduolo in Chiusdino-prov. of Siena, Castle of Rocchette Pannocchieschi-prov. of Grosseto) and of the Prehistory Section of our Department, as well as by the Prehistoric Ecology Section of the Environmental Sciences Department. Actually the database, considering only the Medieval Archaeology Area, is made up of 16.713 records, stored in container, modules and library tables as follows:

- *Ossa animali* (animal bones) container: 5.153 (Poggio Imperiale, Campiglia M.ma, S. Maria del Carmine monastery, Archaeological Map of the province of Siena-Survey project)
- *Macellazioni* (slaughter signs*)* module: 492 (Poggio Imperiale, Campiglia M.ma, S. Maria del Carmine monastery, Archaeological Map of the province of Siena-Survey project)
- *Alterazioni reperti (*alterations) module: 1.347 (Poggio Imperiale, Campiglia M.ma, S. Maria del Carmine monastery, Archaeological Map of the province of Siena-Survey project)
- *Misure reperti* (find measures) module: 4.142 (Poggio Imperiale, Campiglia M.ma, S. Maria del Carmine monastery, Archaeological Map of the province of Siena-Survey project)
- *Riferimenti bibliografia* (literature references) module: 2.260
- *Riferimenti tassonomici* (taxonomical references) library: 24 (Poggio Imperiale, Campiglia M.ma, S. Maria del Carmine monastery)
- *Riferimenti anatomici* (anatomical references) library: 1.034
- *Riferimenti Misure ossa animali* (osteometric measures references) library: 2.261

Two modules have been added to the architecture of the system, in order to manage taphonomical data: the signs of slaughtering found on the bones (table *Macellazioni*) and the traces of alterations caused by natural, animal or anthropic agents (table *Alterazioni reperti*).
A relevant subject in redefining the database system has been dealing with normalization of the language used in data entry, especially in relation to fields containing synthetic information such as species, anatomical identifier, anatomical subtype, number, side, etc. Standardization of terms has been achieved through elaboration of specific vocabularies and *thesauri*. It is of primary importance to keep in mind that faunistic data readability and availability depends heavily on the formal clearness and correctness of these term collections. But it is also true that adopting predefined lists of terms in data entry involves the risk of structural errors, especially if we omit consideration of zoological peculiarities such as osteological differences between species. An example can help us making this concept clear: in entering the record of a bovine incisor, having access to a predefined list about its position containing the generic values "superior" and "inferior" might mislead the user since the only acceptable value in this case in "inferior". During data processing, especially if this happens a fairly long time after data entry, the problems derived from accumulation of similar errors could be a source of problems (typical questions that might arise in such cases are: was it really a bovine incisor and therefore the position value is wrong? Or was it rather an incisor of another species?); in most cases the researcher would be forced to discard the information or newly examine the find (causing useless waste of energy and time, even though such an operation would be possible thanks to an inventory number given to each record of the database and the presence of fields regarding the collocation of each inventory number in the finds deposits). Presence of data entry errors, especially in the case of large samples, is to be considered as "physiological" and cannot be completely avoided; but it is possible to heavily limit such incongruities. This is the reason for providing our database system with three "libraries", which are used to build specific *thesaurus* (value lists).
The first, called *Riferimenti tassonomici*, contains data related to each single species, following the current zoological systematic (class, order, family, etc.). Updating of this library is directly connected with the ongoing of archaeozoological research by database users; in fact the data is entered during laboratory analysis, when a bone fragment belongs to a species that has not been recorded before. It is, by now, clear how problems related to taxonomical determination of a bone fragment have deeply influenced the data structure of the system. Yet another essential question had to be addressed: we applied to the records a systematic based on factors that cannot always be traced back to a single bone fragment. It was therefore necessary to adopt the use of a

specific field, called *Specie schedatura* (recording species), which performs the relationship between the library and the animal bones records. Such a solution allows the researcher to follow personal criteria in defining the most suitable subspecies to identify the studied bone fragments; the values “ox” and “ox1”, for example, might represent two different domestic bovine forms, having morphological diversities but pertaining to the same species *Bos primigenius*.

The second library has been defined as *Riferimenti anatomici* (anatomical references) and contains all osteological elements for each family (*Bovidae*, *Canidae*, *Equidae*, etc.). We decided not to adopt a solution based on the detail of species in order to avoid excessive complexity of the library (differences in the bone’s number and skeletal structure of *taxa* pertaining to the same family are minimal if not totally absent). The usefulness of such a tool is easily conceivable: in the case of the bovine incisor cited above, the value “superior” does never appear in the list of terms associated to the field *Position* since it does not exist in the library; in the same way it will be impossible to enter the fifth metacarpus of a horse or the metatarsus of a cock.

The third (and last) library, called *Misure ossa animali* (osteometric measures), has a direct relationship with the modules *Misure* (measures) and *Riferimenti bibliografici* (literature references); it aims at minimizing the possibility of errors while entering the number of the measure taken on a bone and allows immediate visualization of reference to the relative literature (author, title, pages and the short name of the measure). An example might again help in understanding the feature: if we have to record the osteometric values of a sheep’s humerus, the value that is associated to the measure number will not contain the numbers from 1 to 50 (as it happened in the previous release), but only the possible measures of the specific record. In our case, if we choose the value 1 from the list it means we are measuring the greatest length; references to the literature (Von den Driesch, *A guide to*…) and the short name of the measure (GL) will automatically appear in the appropriate fields.

This solution has also been provided to allow appropriate reading of osteometric data by researchers, especially in consideration of a web version of the system (see the last paragraph of this paper). In this way archaeozoologists would have at their disposal a standardized osteometric dataset, extremely useful in comparisons between samples belonging to different chronological and geographical contexts

Another essential aspect in planning and developing our system has been the evaluation of a proper detail level of data recording; we decided to adopt a very high precision degree, in order to obtain a sort “personal ID” of every single bone fragment. Information quality and processing potentialities are, in fact, directly associated to exhaustiveness in articulation of raw data; the choice about detail in data entry (in other words, deciding the parts of the database to fill in) depends obviously on the single researcher, and is usually influenced by a number of factors such as quality of finds, importance of archaeological sites, particular research interests, time-schedules, etc. What we are trying to explain is that this choice has nothing to do with information technology, but is directly connected with individual recording methods in the study of a specific faunal remains sample. Each case requires careful evaluation of detail level in data entry; if it is limited to a few fields, the potential in terms of data processing will obviously be low. In the experimental cases of Poggio Imperiale (Poggibonsi, Siena) and Campiglia Marittima (Livorno) we tried to reach the maximum precision: a little lengthening in analysis and recording times has been fully rewarded by high speed and potential in the processing phase.

Planning a section dedicated to statistic and quantitative processing has been the last step of a project aiming, from the beginning on, at the production of a tool able not only to store large amounts of records but also (and overall) to allow real time processing of acquired data. Four operations are actually performed automatically by the database: basic statistical analysis, data retrieval and presentation through a simple user interface, exporting of processed information in a text format ready for publication, exporting of data in a tabular format in order to produce charts. The most important of these features is probably the frequency analysis tool, allowing the user to produce find distribution information following personalised criteria; two different solutions have been provided to guarantee an objective processing of the faunal sample, allowing in depth and diversified analysis paths: one based on a hierarchical criteria list and a one leaving totally free choice in the order of the parameters. Hierarchical frequency analysis is based on three large parameter classes, ordered as follows:

I. stratigraphical criteria, involving the fields *Scavo* (excavation), *Anno* (year), *Area* (excavation area), *Settore* (excavation sector), *Quadrato* (excavation square), *Struttura* (excavated structures), *Periodo* (period), *Fase* (phase), *Definizione US stratigrafica* (stratigraphical definition of context), *Definizione US interpretata* (interpreted definition of context), *US* (stratigraphical unit);
II. taxonomical criteria, involving the fields *Classe* (class), *Superordine* (superorder), *Ordine* (order), *Famiglia* (family), *Sottofamiglia* (subfamily), *Genere* (genre), *Specie* (species), *Razza* (race);
III. anatomical and archaeozoological criteria, involving the fields *Specie schedatura* (recording species), *Identificatore anatomico* (anatomical identifier), *Sottotipo anatomico* (anatomical subtype), *Posizione* (position), *Numero* (number), *Lato* (side), *Frammentazione* (fragmentation), *Patologie* (pathologies), *Eta minima* (minimum age), *Eta massima* (maximum age), *Intervallo d'eta* (age range).

It is possible to choose one or more fields from each set; the frequency analysis is based on the combination of all fields in selection order within the single classes, but strictly following the class hierarchy listed above. This means that by choosing the field *Struttura* in the stratigraphical parameters and *Specie schedatura* in the archaeozoological parameters we would get a quantitative distribution of the species in every excavated structure. The free choice solution lets the user decide the sequence of the fields making up the analysis criterion; it is possible, for example, to launch an analysis reversing the order of the fields used in the previous example, obtaining a bone fragments distribution of excavated structures within each species. In both cases the chosen parameters are turned into an analysis identifier, where the combination order of all the fields determines the nature of the statistical output. The results are finally shown in a separate layout table (fig. 5) where the processed data can be visualized and export as described above; obtaining an exhaustive and synthetic representation of the studied bone sample in several formats: database layout, tabular data ready to be charted, ready-for-publication formatted text.

2 - Database Management aspects in the development of the DBMS *Reperti osteologici animali* (*Animal bones* DBMS)

We have so far faced, under a mainly archaeozoological perspective, the most important problems connected with the planning of an efficient animal bones database. This paragraph deals more closely with IT aspects applied to archaeology, obviously focusing on database management and especially describing the structure of the DBMS *Scavo Archeologico* (archaeological excavation) and its subsystem *Reperti osteologici animali* (animal bones).

Applying database management techniques to archaeology means essentially to consider in first place all the specific requirements linked to archaeological research, and subsequently elaborate a data model which can join the strict (and often abstract) logical principles of computer science with the growing facilities of the hardware/software platforms available (in our case a LAN with a Macintosh server, and commercial DBMS applications largely and easily available). We have to point out that it is sometimes hard for cognitive procedures aiming at the production of historiographical models to match the methods of information technology; the problems usually solved by computer analysts concern definitive and irrefutable data, which scarcely need updates or improvements. The same cannot be said of archaeological research (Fronza 2000); during the planning of a database (and, more generally, of a computer solution in archaeology) we have to be very careful about two points: the creation of an open structure which can be integrated at any time with new information and the clear definition of a detail level in recording data. Not considering these two aspects might lead to the creation of inefficient or partial solutions. An open structure is, in fact, strictly connected with the very essence of archaeological research. This is often dynamic and evolves according to the targets of the project; investigations sometimes require a deeper analysis as the project goes on. The consistency of detailed information is directly connected with the efficiency of the database; the ideal solution should match the two different needs: detailed study of particular aspects of the project and profitable data availability.

As we have seen the first release of a database structure for archaeological excavation data has been developed at the LIAAM in 1995 (Valenti, 1998a). A significant redevelopment of the DBMS *Scavo Archeologico* (archaeological excavation) has been carried out between 1997 and 1998, including also the *Reperti osteologici animali* (animal bones) subsystem; this solution is still being used at the Medieval Archaeology Area of our Department, and has undergone another major update during the year 2000.

In designing the data model we followed strictly a few basic rules, pertaining to the approach described above:

- Data structure has to be open, that means it has to be easily adapted and expanded during the feedback processes triggered by archaeozoological research and by the analysis of different bone samples; between 1997 and 2001 the database has been constantly modified and updated in its structure, leaving to research in progress the role of defining the best architecture.
- Data structure has to be exhaustive, that means it has to provide a sufficient number of fields in order to register all different kinds of information derived from an osteological sample; taxonomical, thaphonomical and osteometric aspects have to be considered independently from the diachronical settlement context of the sample.
- The database has to be provided with a simple and intuitive user interface, making data entry and elaboration easy also for researchers without a deep knowledge of computers.
- Readiness in querying and retrieving data has been considered a primary need of researchers; records of single bone fragments have to be quickly and easily isolated, identified and retrieved in relation to the excavated context they come from.
- The database has to drastically reduce the time needed for operations such as frequency analysis of bone distributions and other primary data processing.

<u>*Relational architecture*</u>

The *Scavo Archeologico (*archaeological excavation*)* database management system is based on a relational model presenting a hierarchical tree structure; it is therefore a "vertical" product, with all the advantages and the limits that this implies (Fronza 2000; Fronza 2001). The tree is organized on four levels:

I. The research project with the main data regarding the excavations (table *Scavi*, excavations); it coincides with the concept of archaeological site in a landscape perspective.
II. The spatial, temporal and interpretative partitions of the excavation; involved tables are *Aree* (area), *Settori* (sectors), *Fasi* (phases), *Strutture* (structures), etc.
III. At the third level in the hierarchy we find stratigraphical data with the tables *Attivita* (activities) and *Unita stratigrafiche* (stratigraphical units).
IV. On the lowest level are all the tables (or the subsystems) regarding the different classes of finds.

The actual release of the DBMS *Reperti osteologici animali* (animal bones DBMS) is therefore positioned at this last level and represents an evolution of the hierarchical structure described above; it is based on a loose entity-relationship architecture, configured as a modular subsystem made of three different kind of tables (fig. 2):

- the container *Ossa animali* (animal bones);

- the libraries *Riferimenti tassonomici* (taxonomical references), *Riferimenti anatomici* (anatomical references) and *Misure ossa animali* (osteometric measures);
- the modules *Misure* (measures), *Alterazioni reperti* (finds alterations), *Macellazione* (slaughter signs), *Coordinate reperti* (finds coordinates), *Riferimenti bibliografici* (literature references).

The subsystem DBMS *Bibliografia* (bibliography) is used by one of the libraries.

The container *Ossa animali* (animal bones) represents the master table, at the highest level of the subsystem's architecture. It is linked upwards to the tree of the DBMS *Scavo Archeologico* (archaeological excavation) with the table *Unita stratigrafiche* (stratigraphical units) through a "many-to-one" relationship operating on a SU identifier; the same relationship cardinality, even though with a different meaning (see below), is established with the libraries *Riferimenti tassonomici* (taxonomical references) and *Riferimenti anatomici* (anatomical references) through specific key-fields based on the data of the libraries. On the other hand, it stays at a higher level ("one-to-many" relationship) in respect to the modules *Misure* (measures), *Alterazioni reperti* (finds alterations), *Macellazione* (slaughter signs).

All modules are related to the main table through an identifier (or key-field) based on the inventory number. The tables *Misure* (measures) and *Alterazioni reperti* (finds alterations) are defined as generic modules representing auxiliary tables for all the find classes subsystems; the one on slaughter signs (table *Macellazione*) belongs only to the animal bones database. The module *Coordinate reperti* (finds coordinates), common to all finds, corresponds to an exception in the relationship cardinality, which is in this case "one-to-one" (the module is logically at the same level of the container-master table).

A hierarchical relationship ("many-to-one") is established, as we have seen, between the container *Ossa animali* (animal bones) and the libraries *Riferimenti tassonomici* (taxonomical references) and *Riferimenti anatomici* (anatomical references); this is physically true in the system's architecture, but on a logical level the libraries can not be seen in a hierarchical tree but act transversally on the database structure, supporting a correct data treatment. A third library, called *Misure ossa animali*, completes the animal bones subsystem; the module *Misure* (measures) is related to it with a "many-to-one" relationship. This library is also related to the subsystem DBMS *Bibliografia* (bibliography), since it needs references to methodological literature.

The last two tables of our database are concerned with frequency analysis of finds: *Quantificazione ossa animali main* (main animal bones frequency) e *Quantificazione ossa animali layout* (animal bones frequency layout). The first table acts as a processing tool (the user never has access to it), while the second is employed only in the output of the results (fig. 5).

<u>User interface and automation utilities</u>

The personalized user interface, developed and implemented at the LIAAM, is one of the main advantages of the DBMS *Scavo Archeologico* (archaeological excavation) and of its subsystems; we tried to achieve easiness of use and completeness of available features, through the use of push-buttons palettes, controls, scripts and routines adjusted for each single container table; another concern has been to personalize the graphical look.

At the highest level, the user interface is made of three different environments: *Singoli Archivi* (single archives, allowing creation, modification and querying of data in single tables), *Ambiente relazionale* (relational environment, where it is possible to consult the whole database through thematic relational indexes based on excavation phases, excavated structures, SU, etc.), *Manutenzione* (maintenance, to operate the main preservation functions on the DBMS). Tables are accessed through layouts composed of a central part with the data, surrounded on top and on the left side by a command area with headings and sets of push buttons. The main features provided through the user interface are:

- linear navigation through records;

- operations of record creation, duplication, modification and deletion;
- record marking functions;
- automatic querying and sorting procedures;
- printing routines;
- statistical analysis tools.

In some cases, among which the animal bones subsystem, data complexity (especially the high number of fields) has suggested to divide the visualization layouts in thematic sections (figs. 3, 4).

We have also concentrated on the development of programmed routines aiming at the solution of specific problems in order to simplify repetitive tasks and minimize processing times.

Under this perspective the best example, in the case of the DBMS *Reperti osteologici animali* (animal bones), is represented by the frequency analysis routines. The usefulness of this utility in terms of working productivity is impressive; operations that could take weeks of manual work are performed in a few minutes. Some tests, conducted on a laptop personal computer (Macintosh Powerbook G3, 400 Mhz), illustrate clearly this assumption; a simple frequency analysis by *Specie schedatura* (recording species) on 469 records takes 11 seconds; the same routine on 4.509 records (corresponding to 10.733 bone fragments) takes 1 minute and 52 seconds.

3 - Data sections

As we have seen, in the DBMS *Reperti osteologici animali* (animal bones) the user has access to an interactive environment, made of different windows dedicated to single research subjects (each subjects corresponds to a table in the architecture). In particular there are seven sections (accessible through the buttons located centrally on the screen): six are dedicated to data manipulation (*Main, Misure*-measures*, Macellazione*-slaughter*, Alterazioni*-alterations*, Eta*-age and *Coordinate*-coordinates), while the last one summarizes all the information pertaining to the recorded bone fragment (*Scheda Completa*-complete record).

The *Main* screen is made up of a number of subsections dedicated to data entry of information connected with the excavated context, the find inventory, the taxonomical and anatomical identification and other elements. Data entry in the subsection called *Riferimenti stratigrafici*-context references regards only the fields *Scavo*-excavation, *Area* and *Unita Stratigrafica*-stratigraphic unit, while exhaustive data about every single layer are stored in a dedicated table easily retrievable by the user.

Every find is identified by an inventory number and, if a graphical representation is provided, by a drawing number (*Numero Disegno*); both are written on the bags containing the bones. Our intention is to make sure that a single recorded fragment can be immediately found at any time (even after years).

The section called *Riferimenti tassonomici*-taxonomical references stores zoological references pertaining to the bone fragment and has been implemented in order to allow analysis on larger scales than that of the species (especially in the case of numerically big samples). Data entry of zoological information is accessed through the button located on the upper right part of the screen, which allows the user to interact with the external library called *Riferimenti tassonomici*-taxonomical reference*s*. The table contains fields describing the taxonomical categories of the zoological systematic and a field called *Specie Schedatura*-recording species; this last one represents the identifier of the species, aprioristically determined by the researcher. Such a choice has proved to be necessary in order to avoid problems due to taxonomical identification of bone fragments (as discussed in the first paragraph of this paper).

In the lower part of the screen, under the buttons, you can see the fields related to osteological identification; species (the value list derives from the records of the *Riferimenti tassonomici*-taxonomical references library) and the relative bone fragment, eventually the subtype (as it

happens, for example, for carpal and tarsal bones), the number (in the case of vertebrae or teeth) and the position (teeth and phalanxes).
The value lists of these fields are automatically updated every time the user enters the species. In fact this is obtained through a second library, called *Riferimenti anatomici*-anatomical references; this table contains all the single osteological elements pertaining to a family. Two more fields, also structured with predefined value lists, make the find definition complete: *Lato*-side and *Stato di Frammentazione*-fragmentation.
Another important field is the *Numero di frammenti*-number of fragments; the value of this field depends mainly on the detail level adopted in recording animal bones (for example the unidentifiable fragments of the same context may be catalogued in one record).
Other fields of this section are *Sesso*-sex (entered if identifiable), *Patologie*-presence of pathologies (regarding pathologies we plan, in the future, to build a specific subsection of the database), reference to the physical location of the finds (fields *Luogo*-place and *Cassa*-box), general annotations (field *Osservazioni*).
Osteometric data is stored in a specific module, made up of two fields: *Numero*-number (the identifier) and *Valore*-value of the measure. The value list associated to the identifier derives from a separate table acting as a library of all possible measures for each bone; this should limit the possibilities of errors while entering data and, at the same time, automatically visualize an exact bibliographical reference of each taken measure (author, title, pages and short name).
Two more sections are concerned with thaphonomical aspects derived from the bone segment: slaughtering and alterations; specific modules contain data regarding these features. The first is structured in three fields regarding type of impact evidence, its orientation in respect to the sagittal axe and its position on the bone; the second allows recording of all different kinds of agents (natural, anthropical and animal) that concurred in modifying the original structure of the bone, with a definition of the alteration.
A dedicated section (called *Eta*-age) stores data regarding age of death, when it is possible to derive it from the studied bone fragments; in this case the fields are minimum and maximum age, dental wear (with a reference to author and title), the bone fusion state and the preserved portion.
There is, finally, a module allowing exact location of bone fragments within excavation areas; in this case a preliminary inventory of osteological finds has to be kept during the dig. Exact position of the find (X, Y and Z coordinates taken from fixed points in the excavation area), inclination of the bone and its orientation represent the stored data.

4 - Finalities and future aims

The first experiences in the use of the animal bones database have revealed a flexible and functional tool. The organization of the graphical layout, which orders in a sequence all possible data pertaining to a bone fragment, makes up a real compilation itinerary; this helps the archaeozoologist in a complete observation of the sample. The records are stored in a coherent format, facilitating analysis and information sharing; in some cases data comparison remains still difficult, especially because of standardization problems mainly due to differences in excavation modalities (earth can be sieved or not, excavations can be conducted on large open areas or concentrate on small sectors, etc.): but such problems belong to a wider methodological perspective and do not regard directly the use of the database.
The system has shown its usefulness especially in comparison of osteometric and quantitative data within the same sample as well as across different sites.
The personalised value lists, easily built, help in visualization of categories and subsets during data processing. By using these vocabularies it is quite easy to have immediate observations and numeric consistence of particular groupings. Moreover, the frequency analysis features provides extremely fast analysis, allowing the researcher to explore different directions (which was almost impossible with the manual methods adopted before).

We observed that filling in the digital record sheet for each single bone fragment does not take much longer than the traditional annotation system, especially if we consider the significant reduction of possible errors while recording data due to the presence of the libraries *Riferimenti anatomici* (anatomical references) and *Misure ossa animali* (animal bone measures).
As we have already noticed, the database has been subject to intense (and partly still ongoing) experimenting at the Medieval Archaeology Area and at the Prehistory Section of the Department of Archaeology and Art History of the University of Siena. New data are progressively entered by researchers engaged on different excavation projects, setting up a coordinated method of archaeozoological data storing and processing. We can reasonably claim that we are building a tool which can yield synchronic and diachronic information from the micro-scale (a single site) to a macro-scale (regional, or even larger, inter-site correlations). This represents maybe one of the main potentialities of such a tool.
Further analysis and updates in data structure are also being continued; evolution of the discipline and of technologies, differentiation in research subjects and the large number of stored data will often lead us to revisions and improvements. The next goal, natural but not obvious, is to set up the database on a network; it is possible to imagine a diversified access, on at least two levels: a geographic network and Internet (fig. 6). The first represents an interesting direction to explore; the idea is trying to involve a number of colleagues in order to set up a working team that can test the database on a wide range of situations (recent developments in network technology would make this easily possible). Such a project could be articulated into independent operative units, accessing as clients on a central server-resident database; in other words, each unit would have access to all stored data, but could modify only their own records. In this way each peripheral group would collaborate in the creation of an exceptional tool for the production of important synchronic-diachronic data synthesis; at the same time it would help in widening the range of approaches to the discipline manageable through the database.
Once the data entry and processing of a single project has been completed the information could, if the data owners agree, be published on the Internet and become therefore accessible to a wide range of users. Real time dataflow and information exchange through the world wide web is, by now, a common practice in our society. This is true also for the zooarchaeological community; the international success of the ZOOARCH discussion list is an example that can't be disregarded. We therefore believe that the database architecture proposed in this paper might evolve into a useful tool for archaeozoology, creating favourable conditions for further progress of our discipline; especially because it encourages a fruitful cooperation between specialists that develop and use a common system capable of producing and improving knowledge about the evolution in the models of relation between men and animals, which has been one of the main points of the first Italian national conference of archaeozoology (Albarella 1995, 15).

Appendix (figs. 3, 4)

This appendix describes a stepped operational sequence concerning a data entry example for a bone fragment record within the DBMS *Reperti osteologici animali* (animal bones DBMS):
Step 1 – section MAIN: creation of a new record through the specific button; data entering in the subsection RIFERIMENTI STRATIGRAFICI (stratigraphical references) of the short name of the project (field *Scavo*), the excavation area (field *Area*) and the context number (field *Unita stratigrafica*).
Step 2 – section MAIN: entering, in the subsection RIFERIMENTI SCHEDATURA (record references), of the inventory number (field *Nr. Inventario*) and, eventually, of the drawing number (field *Nr. Disegno*).
Step 3 – section MAIN: entering of the particular recording species in the subsection SPECIE SCHEDATURA.
Step 4 – section MAIN: entering, in the subsection IDENTIFICATORI ANATOMICI (anatomical identifiers), of the bone fragment's characteristics; in particular the user has to fill in the name of

the bone (field *Identificatore anatomico*), eventually the subtype as it happens in the case of teeth, vertebrae carpals, etc. (field *Sottotipo*), the position (field *Posizione*) in the case of teeth (inferior-superior) and phalanxes (anterior-posterior), the number (field *Numero*) if the anatomical element needs it (teeth, vertebrae, etc.), the belonging side (field *Lato*) and, finally, the bone fragmentation (field *Frammentazione*) such as proximal, distal, medio-proximal etc.
Step 5 – section MAIN: entering, in the subsections SESSO (sex) and PATOLOGIA (pathologies), of the respective values pertaining the recorded bone.
Step 6 – section MAIN: entering, in the subsection NUMERO FRAMMENTI (number of fragments), of the total number of fragments having the same characteristics in the sections 1-5; this value can range from a minimum of 1 (a bone fragment recorded by itself, for example the only humerus of ox with slaughtering signs in one particular stratigraphical unit) to "n" (for example 27 unidentifiable fragments found in a stratigraphical unit).
Step 7 – section MISURE-measures: entering of osteometric data; for each measure we have to fill in the identifying number (field *Numero Misura*) and the value in mm (field *Valore*).
Step 8 – section MACELLAZIONE-slaughtering: entering of values regarding the traces of impact visible on the bone fragment; the impact type (field *Tracce*) is expressed by an open (modifiable) *thesaurus*, the evidence's orientation in respect to the sagittal axe (field *Orientamento*) through a *thesaurus* made up of three values (longitudinal, transversal, oblique) and, finally, the position of the evidence (field *Posizione*, to be filled in through an open vocabulary with seven terms: caudal, cranial, dorsal, plantar, medial, lateral, articular).
Step 9 – section ALTERAZIONI-alterations: entering of values referring to eventual evidence of alterations in the original bone structure; the type of the alterations (field *Tipo alterazione*) are expressed by a non-modifiable *thesaurus* of three values (natural, anthropic, animal), while their definition (field *Definizione*) has a non-modifiable thesaurus of 11 values (abrasion, bio-perturbation, fluitation, erosion, fracturing and corrosion due to natural alterations; mastication and gnawing due to animal alterations; boiling, combustion and slaughtering due to anthropic alterations).
Step 10 – section ETÀ - age: in the subsection ETÀ-age the user enters data related to age of death, expressed in months (fields *Eta min.* and *Eta max.*); dental wear is entered in the subsection USURA DENTARIA through the field *Usura dentaria* with an eventual reference to methodological literature in the field *Autore*. The subsection SALDATURA contains data referring to the epiphysial fusion state (field *Stato fusione*) through a *thesaurus* of ten values and the fusion portion through a *thesaurus* of three values (body, articulation, body/articulation).
Step 11 – section COORDINATE - coordinates: entering of spatial references of the bone find within the excavated context; in the subsection COORDINATE-coordinates the user enters measures referring to the three spatial coordinates X, Y, Z with a reference to one of the excavation's points with absolute coordinates. In the subsection POSIZIONE-position the user enters the grade of immersion of the find (field *Inclinazione*) and its orientation in respect to the north (field *Orientamento*).

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Figures captions

Figure 1 – Model of archaeozoological data storing/analyzing process.

Figure 2 – Relational data architecture.

Figure 3 – DBMS *Reperti osteologici animali* (animal bones DBMS). Main functions of the user interface.

Figure 4 – DBMS *Reperti osteologici animali* (animal bones DBMS), section MISURE-measures. Layout of the section with the related table's portal highlighted in dark gray.

Figure 5 – DBMS *Reperti osteologici animali* (animal bones DBMS). Output layout of the frequency analysis feature.

Figure 6 – Data sharing of theDBMS *Reperti osteologici animali* (animal bones DBMS) on a geographic network and on the world wide web (client/server architecture).