36
SYSAND: a system for the archaeological excavations of Anderitum (Javols, Lozère, France)

Andrea Maggiolo-Schettini[1], Paola Seccacini[1], Carmela D. Serratore[1]
Raffaella Pierobon-Benoit[2], Gianluca Soricelli[2]
[1] *Dipartimento di Informatica, Università di Pisa, Pisa, ITALY*
[2] *Dipartimento di Discipline Storiche, Università Federico II, Napoli, ITALY*

36.1 Introduction

Nowadays, computer science offers numerous tools to record and interpret excavation data. Typical requirements of a system for archaeological data manipulation and presentation include:

- the integration of information of different kinds (text, pictures, drawings, maps)
- easy addition and updating of information
- fast response times
- usability on a computer that can be transported to the excavation site.

SYSAND, a system under development for the excavations of Anderitum, a Gallo-Roman town (now Javols, Lozère, France), is intended to satisfy all the above requirements. It is a hypertext system developed using Hypercard on a Macintosh portable computer.

A kernel of the system exists at the moment and has been used experimentally on the excavation site. It records stratigraphic unit cards, checks the consistency of physical relationships, constructs and draws the Harris matrix, and allows the inspection of information associated with each unit (namely general information, materials, drawings, and pictures) by navigating using the matrix and pointing to the desired unit. Programs for acquisition and manipulation of maps are in preparation. Each unit will be associated with maps showing the location of that unit, and it will also be possible to inspect the maps themselves, examining particular areas and, by pointing to the item of interest on the map, to retrieve the information related to that unit.

In the first section of this paper we give a description of the algorithms for computing and drawing the matrix. A full description of the algorithms together with efficiency evaluations and a mathematical proof of correctness and completeness of construction (in the sense that all and only the existing stratigraphic relationships are computed) can be found in Seccacini and Serratore 1993. In the second section we give a general presentation of the system SYSAND which incorporates the above-mentioned algorithms.

36.2 Computing and representing stratigraphic sequences

In this section we describe the algorithm to compute and draw the representation of stratigraphic sequences in the form of a Harris matrix. First, we should recall some basic concepts. In Harris' words,

> "The stratigraphic sequence is the sequence of the deposition of the strata or the creation of the feature interface on a site through the course of time. Unlike most geological columns of strata, the stratigraphic sequence on most archaeological sites cannot be directly equated with the physical order of stratification, as shown in sections. It is rather the translation of those physical relationships into abstract sequential relationships" (Harris 1979).

Units of archaeological stratification (strata or feature interfaces) may have no stratigraphic relationships or may be in one of the following relationships: the *superposition* relationship, where a unit follows the other in time, or the *correlation* relationship, where two units are correlated as parts of the same deposit. The superposition relationship abstracts the following physical relationships between units: 'i lies against j', 'i covers j', 'i cuts j', 'i fills j'. Correlation relationship abstracts the relationships 'i is bound to j' and 'i is equal to j'. In fact, existing superposition relationships between some units are made superfluous by the law of Stratigraphic Succession. This law, established by Harris and Reece (1979), states that the position of a unit of stratification is between the lowest (or earliest) of the units which lie above it and the uppermost of all the units which lie below it and with which the unit has a physical contact, all other superposition relationships being redundant. Non-redundant superposition relationships and correlation relationships can be represented by a diagram called a matrix by Harris. Units on the top of the matrix are the uppermost in the stratification.

The matrix is a graph with nodes representing stratigraphic units and two types of arcs: those from top down, representing superposition relationships, and those between units having a (symmetric) correlation relationship (usually drawn with a double line). In general this graph is not planar, in that it is not always possible to avoid crossing lines by a suitable arrangement of nodes in the plane, and representation of non-existing

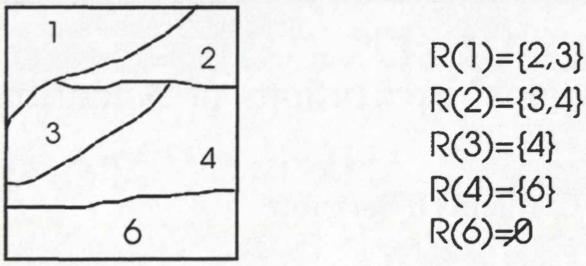

Figure 36.1.

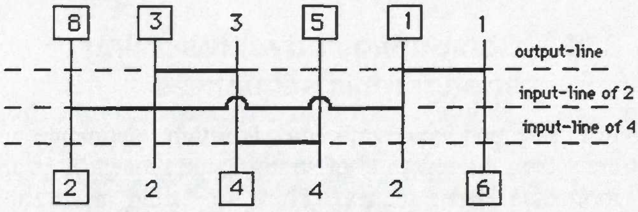

Figure 36.2.

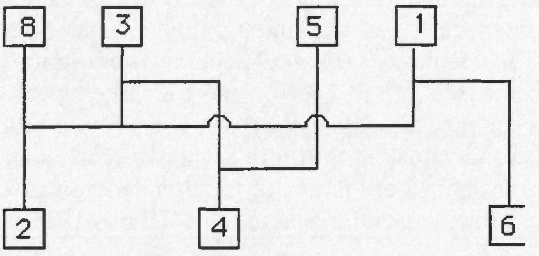

Figure 36.3.

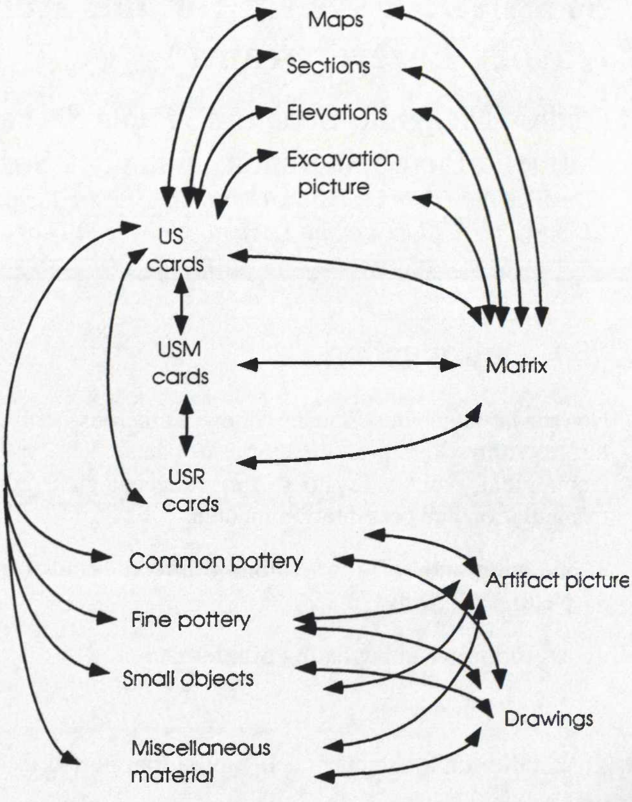

Figure 36.4.

relationships may arise unless some representational convention is used. Correctness and completeness of the produced matrix is recognised to be the major problem. We have seen programs which give an incorrect matrix, in that the layout shows some units result to be related when they are not. There are also solutions which are clearly incomplete, such as that described by Bridger and Herzog (1991) and Herzog (1993) where, through interaction with the user, it attempts to draw a matrix without intersecting lines and, if this is not possible, some connections are not drawn and units lacking such connections are marked in a special manner.

We now describe our solution. For each unit i we consider the set of its underlying units, namely the set R(i) of all units j such that either 'i lies against j' or 'i covers j' or 'i cuts j' or 'i fills j'. Figure 36.1 illustrates an example of stratification in section and the corresponding sets R(i). We say that j is *reachable from* i *in* q *steps* if there is a sequence of units $j_1 \ldots j_{q-1}$ such that j_1 belongs to R(i), j_2 belongs to R(j_1)... j belongs to R(j_{q-1}). If j belongs to R(i) we says that j is *reachable from* i *in one step.* In the example shown (Figure 36.1), we have the following: 3 is reachable from 1 in 2 steps, 4 is reachable from 1 in 2 steps, 4 is reachable from 1 in 3 steps. A unit j is *i-redundant* if it is in R(i) and is reachable from i in more than one step. Let $\overline{R}$ (i) be the set of all units j such that j belongs R(i) and j is not i-redundant. We call $\overline{R}$ (i) the *non-redundant set* of underlying units of i. The sets $\overline{R}$ (i) represent the stratigraphic relationship of *superposition* between units. For each unit i we consider the set of its correlated units, namely the set E(i) of all units j such that either 'i is equal to j' or 'i is bound to j'. The sets E(i) represent the stratigraphic relationship of *correlation* between units. A first algorithm computes the set $\overline{R}$ (i) for each i. In the worst case the complexity of the algorithm is of the order of n^3, with n number of units (see Seccacini and Serratore 1993 for the evaluation).

A Harris matrix represents the units and the two types of relationships between units. If two units i and j are in a (stratigraphic) superposition relationship they must be on two different levels, i above j and i connected with j. If two units i and j are in a (stratigraphic) correlation relationship they must be on the same level with a double line connecting i with j. If the matrix is to represent both the relationships correctly, unwanted connections must be avoided. This may be done with a suitable layout that avoids unwanted crossing of lines or else use a special representation that is interpreted by the reader in the right manner. Moreover, from what has been said before, it follows we must properly place chains of units, as well as single units, where a chain represents the symmetric transitive closure of the correlation relationship. An

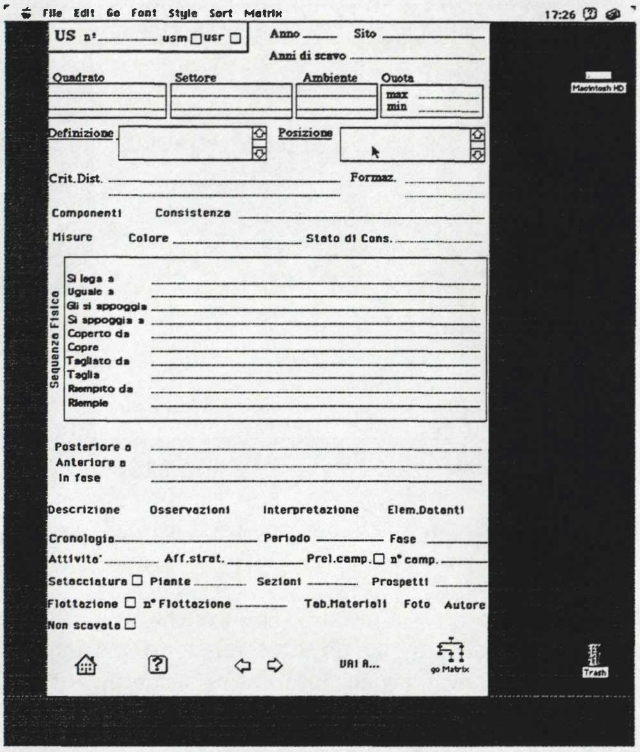

Figure 36.5: US card format.

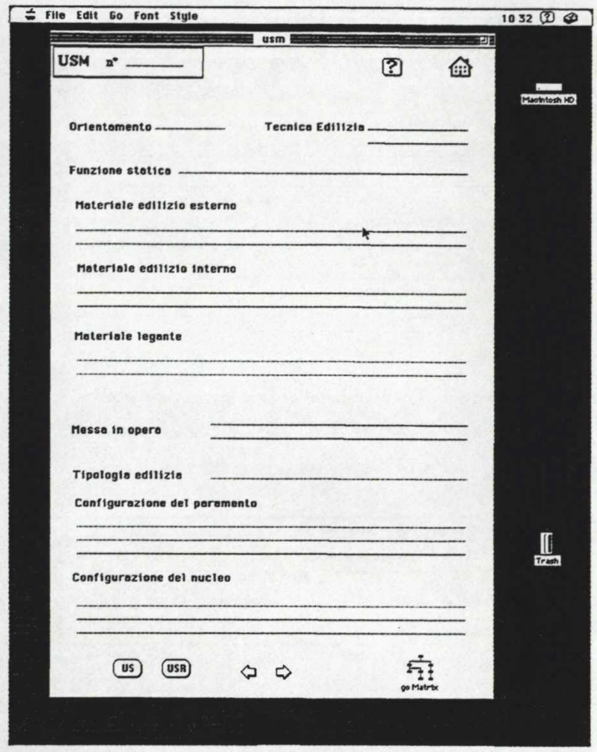

Figure 36.6: USM card format.

entire chain of units will be placed on a level, but care will be taken that elements of a chain do not inherit superposition relationships one from the other. A second algorithm constructs and draws the matrix, performing the following steps:

1. Chains of units are computed.
2. On the layout vertical segments are disposed representing pairs i, j such that j belongs to $\overline{R}$ (i).
3. For each unit a representative is chosen, taking into account that units in a chain must be near to each other.
4. Connectors are drawn to allow more units to be superposed on a unit and for a unit to have more units on which it is superposed (with bridges allowed to avoid wrong connections).
5. Finally, double lines are drawn to represent the correlation relationships (see Figure 36.2, where chosen representatives are shown as boxes and connectors are in bold face).

The layout that finally is printed is the one shown in Figure 36.3. The complexity of the algorithm is of the order of m • n where n is the number of units and

$$m = \sum_{i=1}^{n} \left|\overline{R}(i)\right|$$

36.3 SYSAND: a system for archaeological excavations

SYSAND is a hypertext system for the integrated management of all information, numerical, textual and pictorial, that has been collected for each stratigraphic unit. The main idea of SYSAND is to use the matrix as a means for accessing all this documentation. The matrix can be created and, by clicking on a node representing a unit, the information related to the unit can be accessed. The following is a general description of the system of which so far only a kernel has been completely developed.

Let us examine first the type of cards one has for each unit. As well as the stratification unit card (*US* card), one may also have the following cards:

- a *USM* card if the unit is a wall
- a *USR* card if the US is a wall and the wall has a covering or if the US is a pavement which is covered, for instance by a mosaic. In the former case there will be a USM card and a USR card as well, in the latter case there will be no USM card.
- a card for artefacts of common pottery (*Ceramica comune*),
- a card for fine pottery (*Ceramica fine*),
- a card for small objects (*Piccoli oggetti*),
- a card for miscellaneous material (*Miscellanea*).

Pictures, maps, sections, and elevations may also be related to the unit. Furthermore, pictures and drawings of artefacts may be related to the cards for pottery, small objects and miscellaneous material. The various stacks of cards will be connected as shown in Figure 36.4. In the kernel of the system working at present there are only the four stacks US, USM, USR and MATRIX connected.

We now describe the system as it appears to a user having selected the SYSAND card. Clicking on the icon "Schede US" one may consult existing cards, if any, or

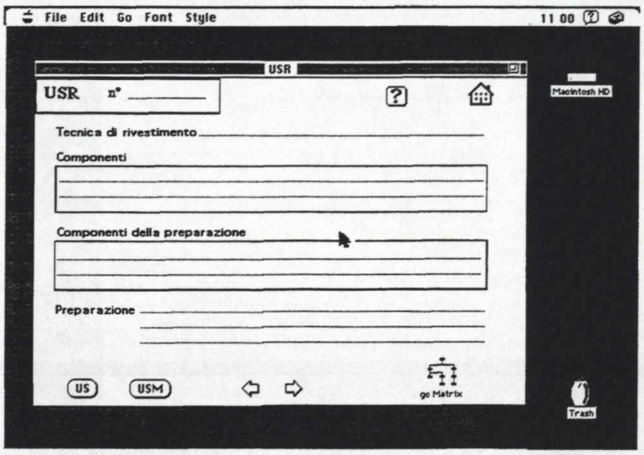

Figure 36.7: USR card format.

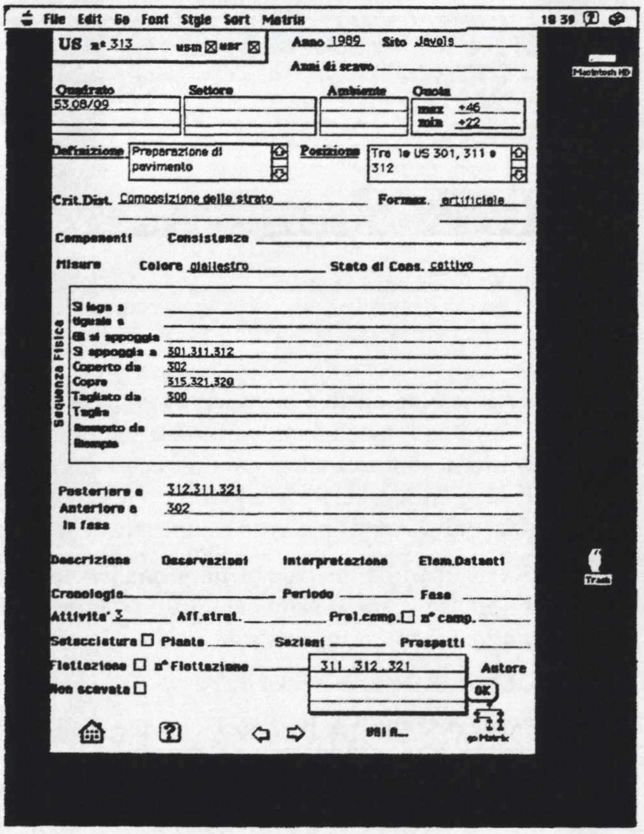

Figure 36.8.

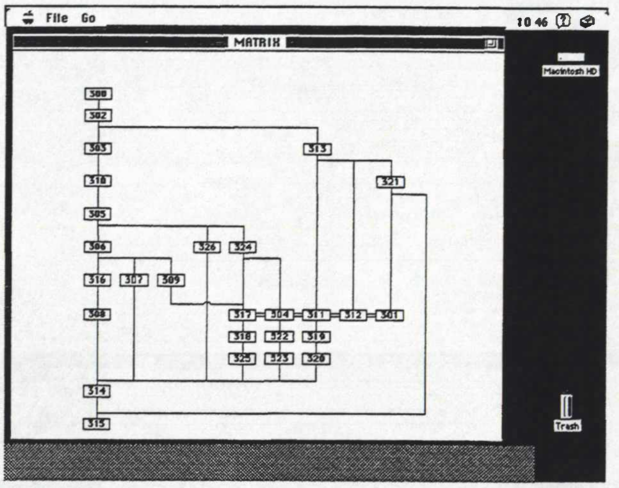

Figure 36.9: An example of produced matrix.

insert a new card. The format of the US card is shown in Figure 36.5). Controls ensure that duplicate US numbers or invalid types of data (for instance unit numbers that are not integer numbers) cannot be entered. If a USM card or a USR card (or both) is to be associated with the US card, the required card will appear on clicking the appropriate button (Figures 36.6 and 36.7). Buttons in both the USM and USR cards allow the user to return to the US card to which they are associated. Cards can be ordered either by year or by number by choosing the relevant item in sort menu, which allows the stacks of cards to be visited in either of the two orders.

The procedure that computes stratigraphic sequences can be selected using the Calculate Stratigraphy menu item in the *Matrix* menu. The system will check for inconsistencies in the physical relationships and issue error messages if any are found. For instance, if the card for unit 100 contains the relationship '100 covers 101', the card for unit 101 should have the symmetrical relationship '101 is covered by 100', otherwise an error message is displayed. During this phase, a hidden field in each US card contains the set of units to which the current unit is superposed. An example result is shown in Figure 36.8. Clicking on a number in this set will display the corresponding US card. This allows cards along the lines of the superposition relationship to be visited. Once the stratigraphy has been computed, the matrix can be drawn on the screen. In Figure 36.9 we see the matrix for a sample of twenty seven units. If the matrix exceeds the size of the card (which is set by the programmer) the matrix will be partitioned into successive cards (for example, Figure 36.10). The Next and Prev options on the Hypercard *Go* menu can be used to visit the next and previous cards.

The matrix can be also viewed by clicking on the Matrix icon in the SYSAND card to examine an already computed matrix. Clicking on a node in the matrix produces a menu with as many items as there are cards (US, USM, USR,...) associated with that unit (see Figure 36.11). There is also a "go matrix" button on the US, USM and USR cards which can be used to view the already created matrix. The portion of matrix that contains the unit from which the request was made will be shown, with that unit or node highlighted.

36.4 Further work

During or following excavation, a number of units may be identified as constituting a single phase and it may be useful to represent the stratigraphic sequencing of these phases. The same may also be true for phases constituting only one period. Sometimes the stratigraphic sequence of a site may be gradually constructed from partial stratigraphic evidence that has been already acquired. As a result, several matrices may need to be combined into one. All these possibilities are being addressed by

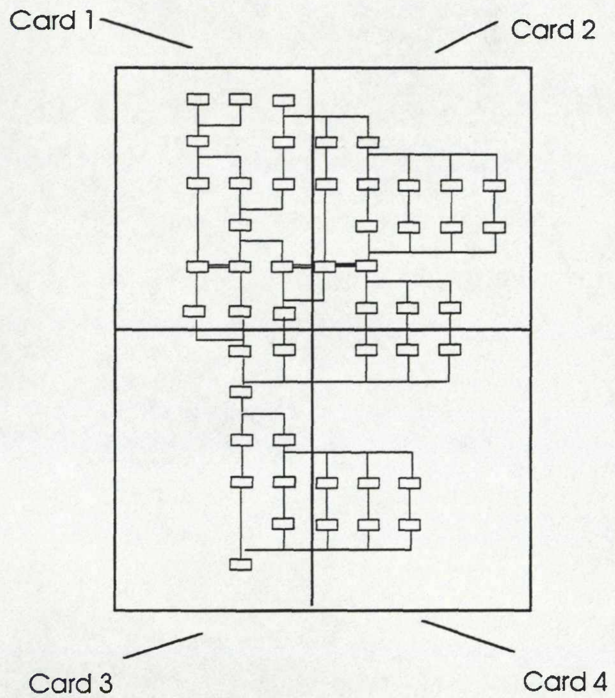

Figure 36.10.

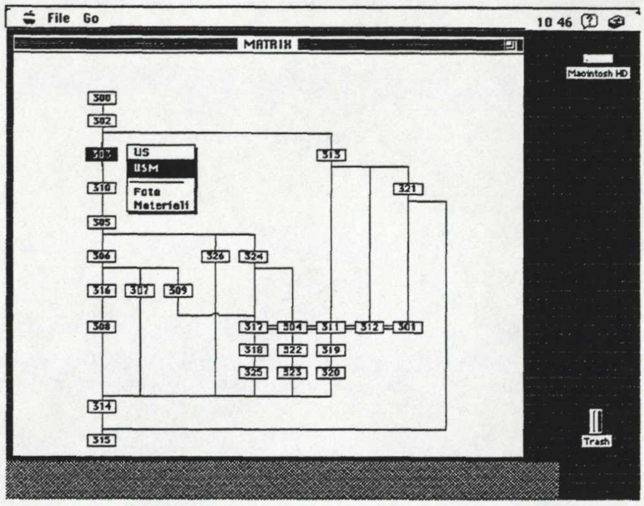

Figure 36.11.

algorithms that are under study at present. Programs for the acquisition and manipulation of maps are also in preparation. Each unit will be associated with maps showing its location, and it will also be possible to use the maps to identify a unit and retrieve the information (US, USM, USR, cards for materials, and so on) relating to that unit.

References

BRIDGER, C. & HERZOG, I. 1991. 'Die Stratigraphische Method und ein neues pc-Programm zur erstellung der Harris-Matrix', *Archäologisches Korrespondenzblatt*, 2, 33–144.

HERZOG, I. 1993. 'Computer-aided Harris Matrix generation', in *Principles of Archaeological Stratigraphy*, Academic Press, London.

CARANDINI, A. 1991. *Storia dalla Terra: manuale di scavo archeologico*, Einaudi, Torino.

HARRIS, E. C. 1979. *Principles of Archaelogical Stratigraphy*, Academic Press, London.

HARRIS, E. C. & REECE, R.1979. 'An Aid for the Study of Artefacts from Stratified Sites', *Archaeologie en Bretagne*, 20–21, 27–34.

SECCACINI, P. & SERRATORE, C. D. 1993. *Elaborazione e rappresentazione di stratigrafie in un sistema di dati archeologici*, Tesi di laurea in Scienze dell'Informazione, Università di Pisa, aa. 1992–1993.