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The Harris Matrix Composer

A New Tool To Manage Archaeological Stratigraphy

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Abstract: The Harris Matrix - formulated by Dr. Edward C. Harris in 1973 - is the established way of representing the archaeological stratigraphy of an excavation. The Harris Matrix is a sequential diagram defining relations between stratigraphic units. It is an important method to document the stratification that is destroyed by the excavation process and hence a vital tool for analysis. In this paper a new application is introduced, called Harris Matrix Composer (HMC) that allows creating and editing Harris Matrices with an intuitive graphical interface. Dr. Harris was involved in the evaluation of early prototypes to guarantee compliance with his theory. User tests were undertaken to address usability problems. The HMC supports valid Harris Matrix creation and indicates invalid units and relations. The theory has been extended to allow for temporal relations as well. Furthermore units can be grouped into structural entities called phases and into periods, assigning them to a historical epoch.

Keywords: Harris Matrix, Archaeological Stratigraphy, Excavation Management and Analysis

Introduction

Every archaeological site is stratified and any archaeological stratification is unique. Stratigraphy, the description and interpretation of stratification, is the main key for any further analysis of archaeological finds. Excavation is both costly and destructive. The recording process, which takes place during excavation aims at dividing the stratification into its components, the units of stratification. This is done by removing single deposits in the reverse order to which they were formed. Any unit of stratification has to be destroyed as the excavation proceeds to the next one. It is therefore absolutely necessary to document each stratification unit by recording its physical and spatial properties and stratigraphic relations, while collecting finds and samples in relation to it as accurately as possible (NEUBAUER, W., 2007).

The stratigraphic excavation method, as defined by E.C. Harris (HARRIS, E.C., 1989) makes it possible to record the single units of stratification (i.e. deposits and surfaces) along with all its attributes and relations, and to create a stratigraphic sequence from this data. Such a sequence is known as Harris Matrix (Fig. 1). As Harris points out, every unit of stratification is formed by material (deposits) and immaterial aspects (surfaces or interfaces) that have to be found and recorded by the excavating archaeologist.

In the first instance these two aspects are the main objects to be recorded on a stratigraphic excavation. Any finds, samples, or other information and observations have to be related to the deposits and surfaces, i.e. the units of stratification, for the subsequent analysis.

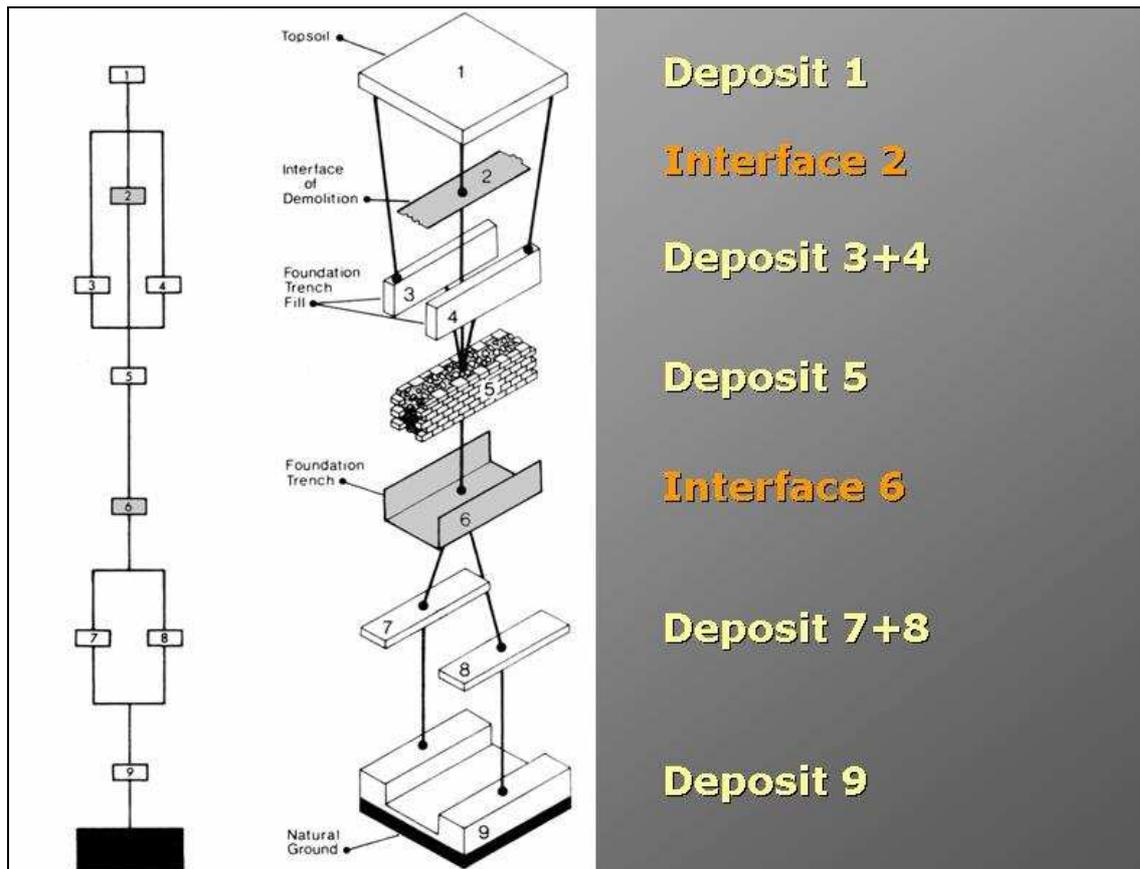


Fig. 1 – Creation of a stratigraphic sequence as defined by E.C. Harris 1989.

Terrestrial laser scanners combined with digital imagery are the most effective tools for stratigraphic recording to date and provide the ability to reconstruct the excavated volumes and specific surfaces in 3D space (NEUBAUER, W., 2007; DONEUS, M. & NEUBAUER, W., 2005a). Therefore, 3D recording of the top and the bottom surface of any single deposit, as well as the 3D recording of specific interfacial surfaces is necessary to reconstruct fully any part of a site destroyed during the process of excavation (NEUBAUER, W., 2008a).

During recording every single unit – surface or deposit – is given a unique number and documented by its boundary polygon, as well as its topography. The collected point-clouds from specific surfaces, the surfaces of deposits and the associated texture derived from digital photographs are the primary raw data and processed in a Geographical Information System (GIS). In that way the geo-referenced data is immediately available for on-site analysis (NEUBAUER, W. & DONEUS, M., 2008).

Surfaces, the immaterial aspect of stratification, can therefore be captured in their entirety. By their nature, the material aspects of deposits can only be captured by sampling. For the stratigraphic record, each deposit, as represented by its top and bottom surface is reduced to a unique number in the Harris Matrix. It imparts this number to all of the portable finds and samples found within its volume. Their 3D position can be easily defined upon discovery or extraction. All additional attributable data, such as descriptions of surfaces and deposits and the finds database are integrated into the GIS.

As GIS provides the ability to store, visualise and analyse graphical information in combination with descriptive information, it is a perfect general tool for the visualization and analysis of excavation results. The outstanding value of a GIS is its ability to reproduce the complete record of a stratigraphic surface as well as any related descriptive information (DONEUS, M., NEUBAUER, W., STUDNICKA, N., 2003; HARRIS, E.C., 2001).

The stratigraphic recording of an excavation as described above results in a vast volume of digital archaeological data. This data needs to be ordered by setting the correct stratigraphic relations. GIS do not provide such a feature. Usually it just allows arranging data sets into a tree-like hierarchy that has nothing to do with stratigraphic relations.

The Harris Matrix is de facto the standard method of defining stratigraphic relations. Thus a tool is needed that allows creation and editing of a Harris Matrix during stratigraphic recording. This tool can then be used to provide the GIS with the necessary stratigraphic relations and to manage digital archaeological data stored by it in a meaningful way for analysis. Since no tool is available that completely complies with the theory of E.C. Harris (HARRIS, E.C., 1989), let alone provide an interface to GIS, we decided to design and develop a new one, which is called Harris Matrix Composer (HMC).

Requirements for a Harris Matrix Tool

Requirements have been acquired in close cooperation with archaeologists. Reported experiences with other tools have been taken into account. The practice of documenting stratigraphic relations by other means has been studied in the field, observing archaeologist on excavation sites. This revealed that a standardized method has not yet prevailed. People were filling lists of stratigraphic relations either with standard text editors or on printed templates. If these lists were later translated into Harris Matrices at all, it was done by using diagram editors or by pen and pencil, - a clear sign that an appropriate tool is still missing.

The creation of a Harris Matrix has in fact to parts. The first stage is the creation of a correct stratigraphic sequence. Units of stratification are either deposits or surfaces. Each excavation is enclosed between the top surface and the interface to geology, marking the start and end of the process. The first stage is based entirely upon the analysis of the topographical record and topology by defining the stratigraphic relations “above” and “below” or “none”. The first stage is finished right after the excavation.

The second part is the division of the sequence into so called phases and periods. It depends on additional information based on structural (phase) and temporal (period) analysis of the stratigraphic record. The first stage can be done during the excavation and is not related to any find analysis. The Harris Matrix can be created without any respect to the archaeological finds. They have to be integrated in the second stage when the units of stratification are grouped according to structural or temporal arguments into phases and periods.

The creation of a Harris Matrix does not consider any temporal relations between units that might be deduced from related finds in the subsequent analysis. Stratigraphic relations imply temporal relations. But it is not possible to explicitly set temporal relations between stratigraphical unrelated units. So we proposed to extend the theory by incorporating the temporal relations “later” and “contemporary”. This has been discussed with E.C. Harris and he liked the idea.

One of the most important requirements concerns usability. The tool should provide an efficient way of building up a Harris Matrix during stratigraphic recording. This implies a Graphical User Interface (GUI) that is intuitive and easy to comprehend. Familiar and well established paradigms of interaction as known from widely used drawing tools need to be considered.

The Harris Matrix is created by direct manipulation. Thereby the user should be freed from the task of doing a layout. The tool should automatically arrange the graph structure according to the theory. Most important is that the layering of units, which determines their vertical arrangement, reflects the stratigraphic sequence and thus their temporal succession. This means that all lines representing the relation “above” point from top to bottom connecting two units on different layers, which correspond to different time slots. The same is true for lines representing the temporal relation “later”, while lines representing the relation “contemporary” are bi-directional horizontal lines, because they connect units that are placed on the same layer, i.e. belonging to the same time slot.

Usually a Harris Matrix quickly becomes very large, so that sophisticated navigation methods are essential. It is necessary to zoom and pan efficiently but also provide a mechanism to jump and focus to a certain unit, phase or period. User tests with early prototypes revealed that a search function is desired. The tool should also be able to remember the locations in the matrix that has been most recently edited.

A pedagogical requirement has also been identified. The tool should support its users to create valid Harris Matrices that fully comply with the theory. Invalid relations, like cycles and invalid units, like those with missing relations are indicated and an explanation is given. This validation check helps students to better understand the concept and strengthens learning by doing. In that way it should also help to spread the method of stratigraphic excavation. The validation check is also an aid for professionals showing them mistakes or missing input. However it must not hinder users to proceed with building the stratigraphic sequence but just give them a hint that there is something to resolve to obtain a valid Harris Matrix.

Design of the HMC

The Graph Editor

The heart of the HMC is the graph editor, where the Harris Matrix is composed (see Fig. 2). It starts with a minimal but valid Harris Matrix, consisting of the top surface, the interface to geology and a special unit called “Unexcavated” that represents the unexcavated archaeological stratification. As long as this unit cannot be deleted without invalidating the Harris Matrix the stratigraphy is not finished.

Users add either deposits or surfaces by choosing the appropriate tool from the toolbar and clicking somewhere on the background of the graph editor. The new units automatically move to the top layer and build a sequence there, like birds on a wire. This is because their final position depends on their stratigraphic relations, which have yet to be set. Each unit of stratification except the preset top surface and the interface to geology must be set in stratigraphic relation with at least one unit above and at least one below it to be valid. As long as these relations are not set these units are marked as invalid.

To set stratigraphic relations the users draw a line with an arrow head between two units. This line represents the relation “above” and means that the unit where the line starts lies above the unit where the line points to. There is no extra tool for the relation “below” because for that the line only needs to be drawn in the opposite direction. Most invalid relations are recognized as they are drawn and declined, for example if a user tries to set a unit above the top surface. An explanation is then given in the status bar.

Other invalid or impossible relations are only recognized by analysing the whole Harris Matrix, which does not work in real time. This especially concerns transitive and cyclic lines. Users can trigger a validity check whenever they like. The Harris Matrix is then analysed using methods from graph theory. Transitive lines are automatically removed, i.e. if unit A lies above unit B and B above unit C then the relation “A above C” is transitive and redundant.

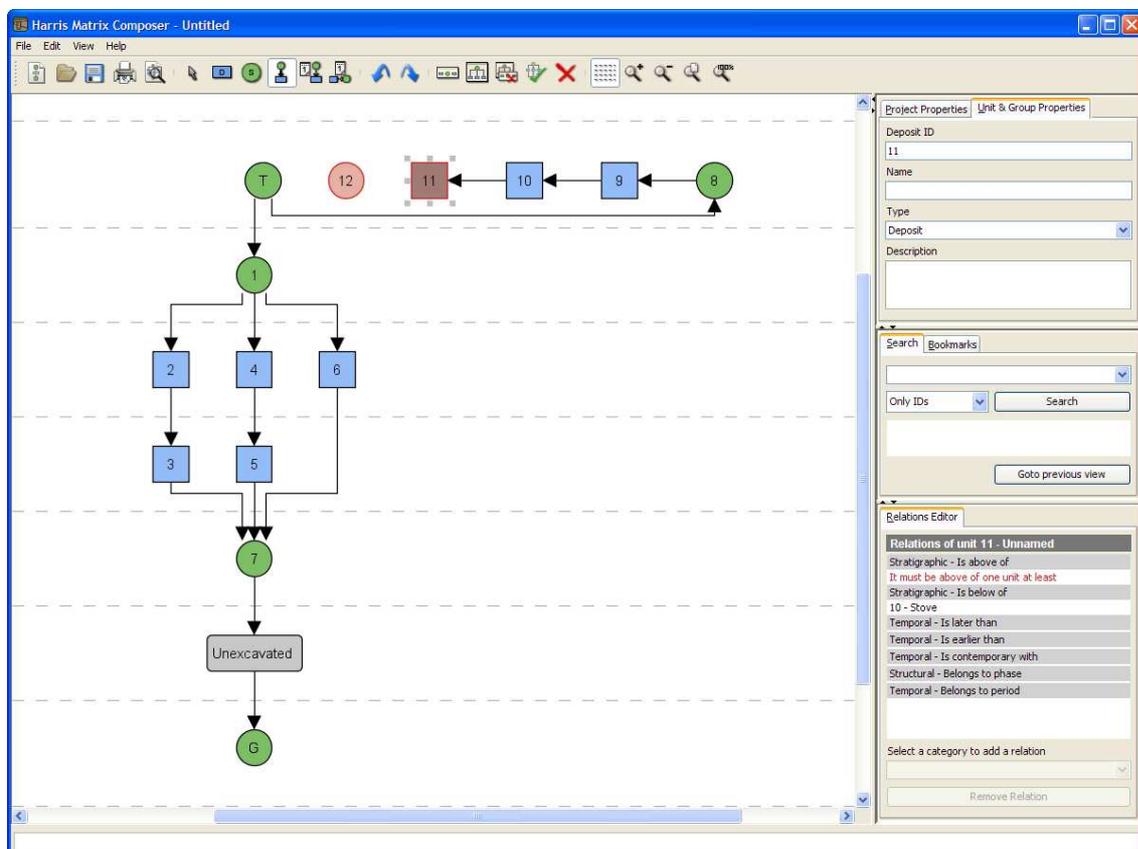


Fig. 2 – Composing of a Harris Matrix with the graph editor.

Cycles represent a physically impossible stratification because when unit A is above unit B and B above C then C cannot be above A. Cycles are detected by the validity check and the corresponding lines are marked as invalid (see Fig. 3). This is a clear composing mistake and needs to be resolved by the user since the application cannot know, which line in the cycle the wrong one is. An exception are loops to the same unit, which are declined in real time and cycles between two units, in which case the direction of the line is reversed, i.e. when A lies above B and the users draws a line from B to A then this line is kept and the one from A to B is automatically removed.

The Harris Matrix can be set into a layout that complies with the theory. All units are then moved to the layer that corresponds with their stratigraphic relations. This means that all lines are vertical lines pointing from top to bottom as one would assume for the lines representing the relation “above” (see Fig. 4). The layout algorithm can only be applied to a valid Harris Matrix. It cannot resolve invalid units that have missing relations or cyclic lines. Therefore validity check and layout are combined to one function.

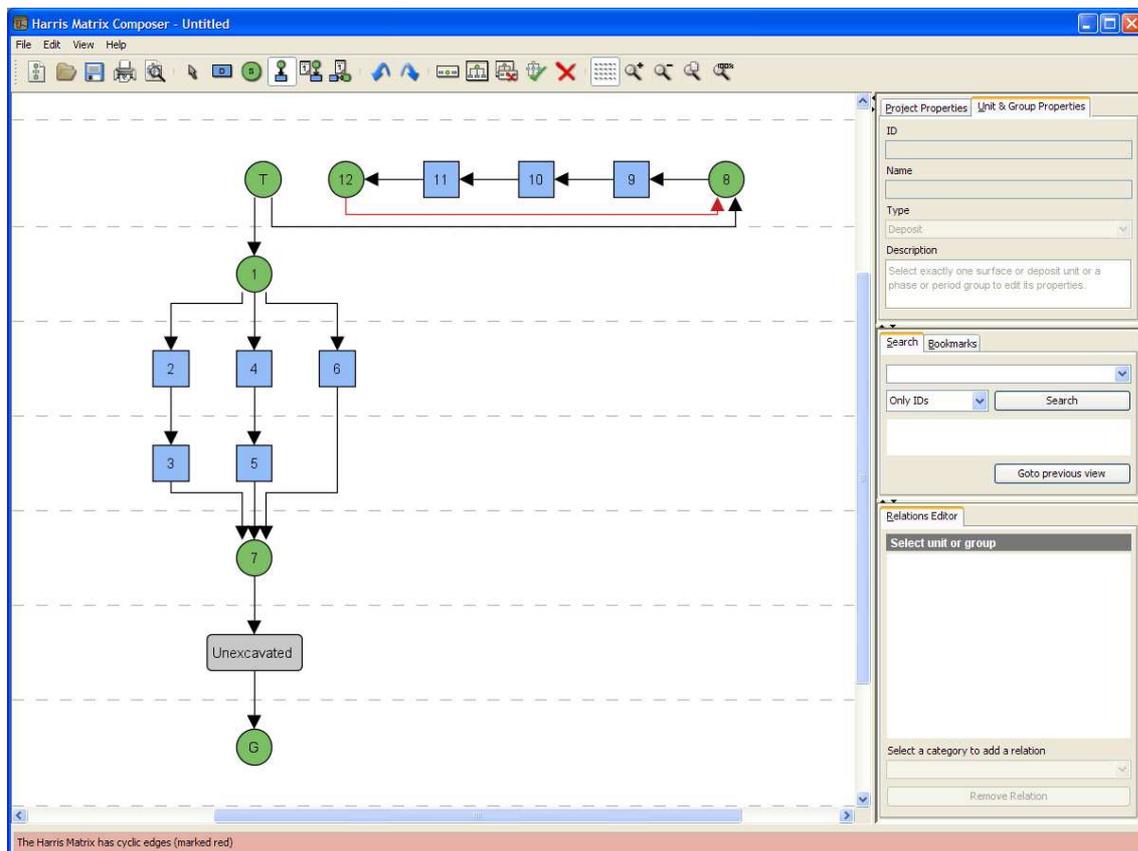


Fig. 3 – A cycle has been detected by the validity check and marked red.

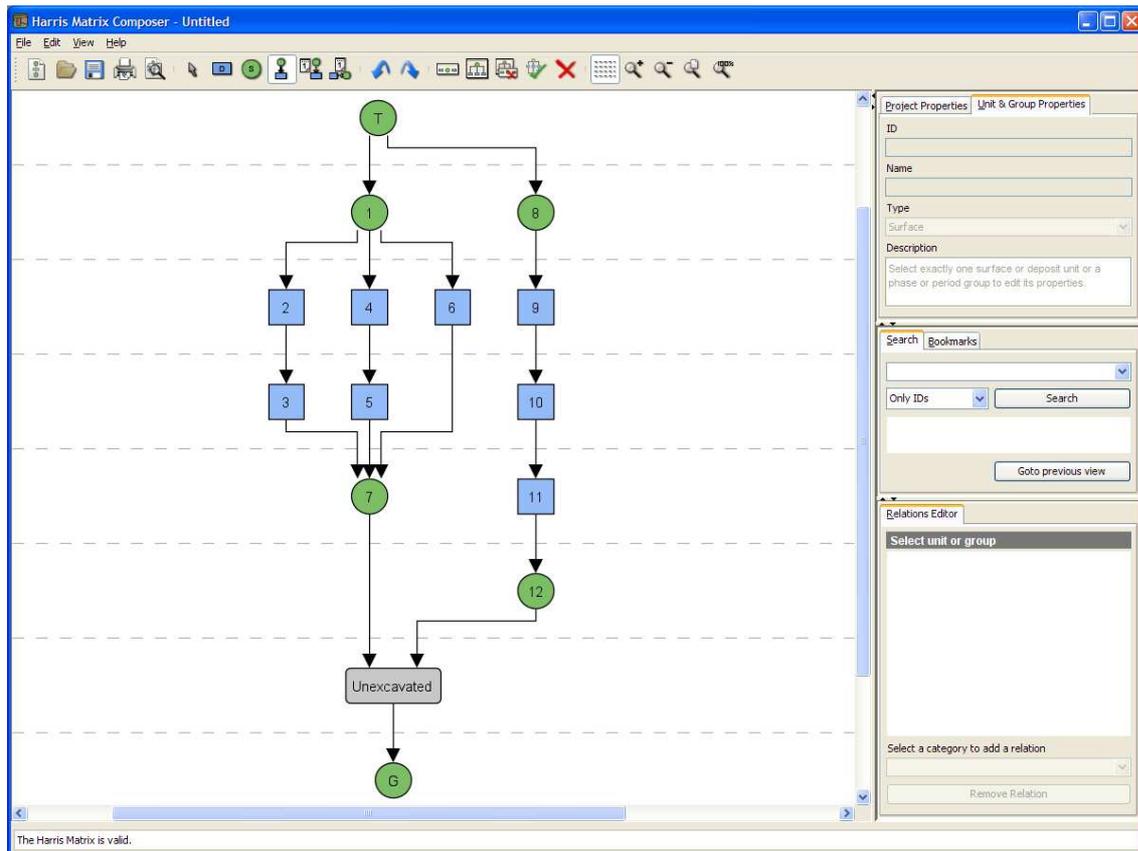


Fig. 4 – A valid Harris Matrix in the correct layout.

Temporal Relations

As mentioned above we extended the theory to allow explicit temporal relations. Stratigraphic relations imply temporal ones. But analysis of the stratigraphic record might yield additional, non topological arguments to define extra temporal relations between units. Users can either set a source unit to be later than a target unit or set both units as contemporary. The relation “earlier” is obtained by drawing a “later” line in the opposite direction.

Temporal relations are represented by dotted lines in a different colour. Lines meaning “later” point to the unit that is earlier than the one the line originates from. Contemporary is a bi-directional relation shown by lines with arrows at both end points (see Fig. 5).

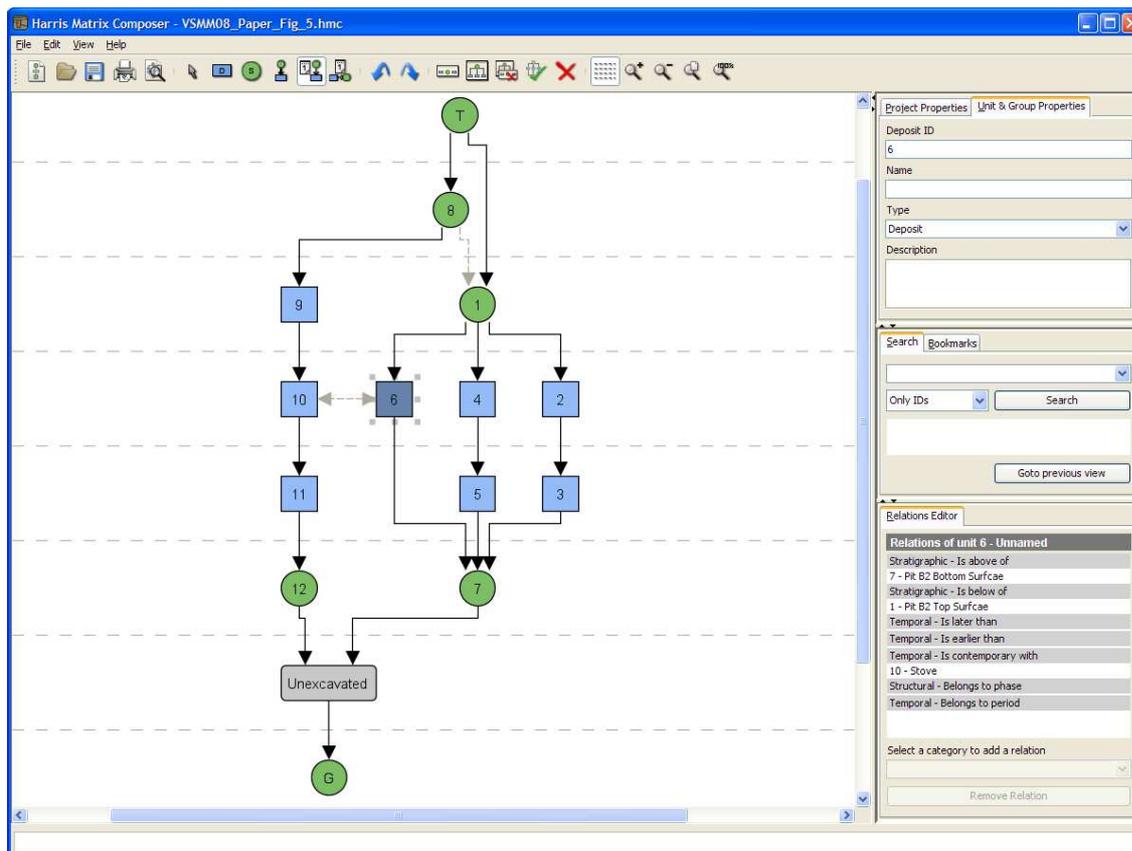


Fig. 5 – A Harris Matrix with temporal relations “later” and “contemporary”.

Temporal relations are considered for validation and layout. They can be transitive with respect to themselves but also with respect to stratigraphic relations. Any stratigraphic relation “above” also implies the temporal relation “later”. Temporal relations that are transitive in one or the other way are removed by the validity check. For example when unit A is above B and B above C then the relation “A later than C” is redundant and removed. Likewise cycles are recognized, also with respect to stratigraphic relations.

The temporal relation “later” has similar effects on the layout as the stratigraphic relation “above”. It positions units on appropriate layers so that these lines always point from top to bottom. In contrast contemporary units are placed on the same layer so that the lines representing them are horizontal.

Phases and Periods

During analysis of the stratigraphic record units might be assigned to a structure and/or to a period as described above. User can select units and group them into a phase, which represents a structural entity, for example post-holes remaining from an ancient dwelling. Phases cannot be nested but can belong to periods.

Periods represent a certain historical epoch. Units and phases are assigned to a period by selecting them in the Harris Matrix and use the appropriate grouping operator. Periods cannot be nested and encompass units that lie on different layers since the vertical position also has a temporal meaning. In

the current design neither phases nor periods can have any relations. They are solely defined by the stratigraphic units they contain.

Both phases and periods appear as boxes that encompass the items grouped into them. These boxes can be collapsed one by one or all at once to make the Harris Matrix more compact. When collapsed their content is not shown and the group appears as small box with a label (see Fig. 6). Of course each collapsed group box can be expanded again.

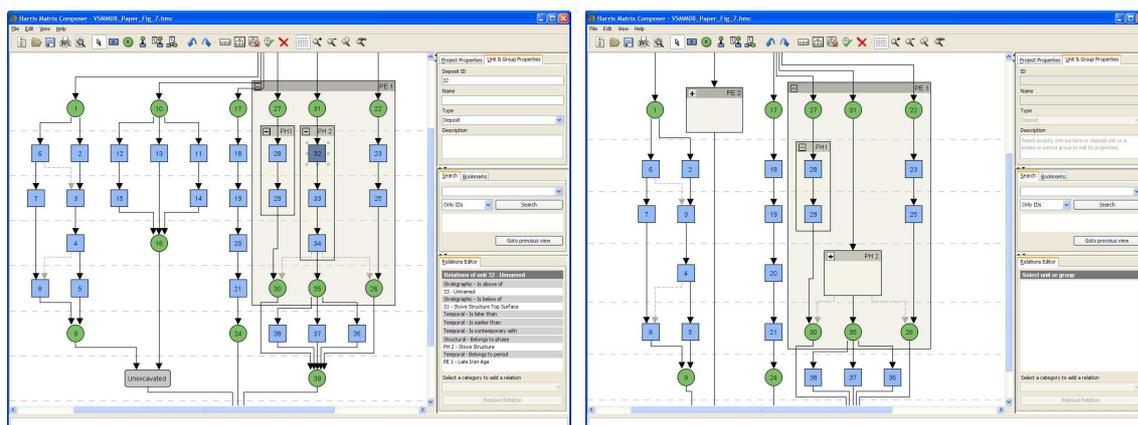


Fig. 6 – A Harris Matrix with phases and periods, the right picture shows collapsed ones.

Navigation

A typical Harris Matrix is rather large. Hence efficient and convenient navigation techniques are important. There are two types of navigating through the graph structure, by direct manipulation of the graph view and by searching for units and jumping to bookmarks.

Direct navigation is achieved by panning and zooming. Panning works by dragging the mouse, which is analogue to shifting a sheet of paper with the hand. Zooming is done by the mouse wheel. Users can rapidly change to a completely different view by resetting the zoom factor so that the whole Harris Matrix is shown and then use a tool to draw a frame around that part, which should be magnified to the window's size.

A full text search can be initiated by the search panel. All the data associated with units can be searched, i.e. its id, name and description. A list of results is shown and when clicking on an item the view of the graph smoothly changes to the found unit, so that it appears in the centre in normal size. A view can also be bookmarked and later looked up in the bookmark panel. In this way users can store interesting points or locations that are currently edited and efficiently jump between them.

The Properties Panel

The project properties editor of this panel allows naming the project, writing a description and referring to the excavation site. When a unit is selected in the Harris Matrix the panel automatically shows the unit properties editor. Here the unique identifier of units can be changed. It is set automatically while composing by using consecutive numbers. The application refuses to change the identifier if it is not

set to a unique alpha-numeric value. This is important for retrieval from the GIS or an external database.

Other properties for units are a name, a description and its type, namely either deposit or surface, which can also be changed by this editor. The unique id appears as label of the graphical representation of units in the graph editor. All other properties appear in a balloon when moving with the mouse over a unit (see Fig. 7). Phases and periods can also be assigned a unique id, a name and a description by selecting them and using this editor.

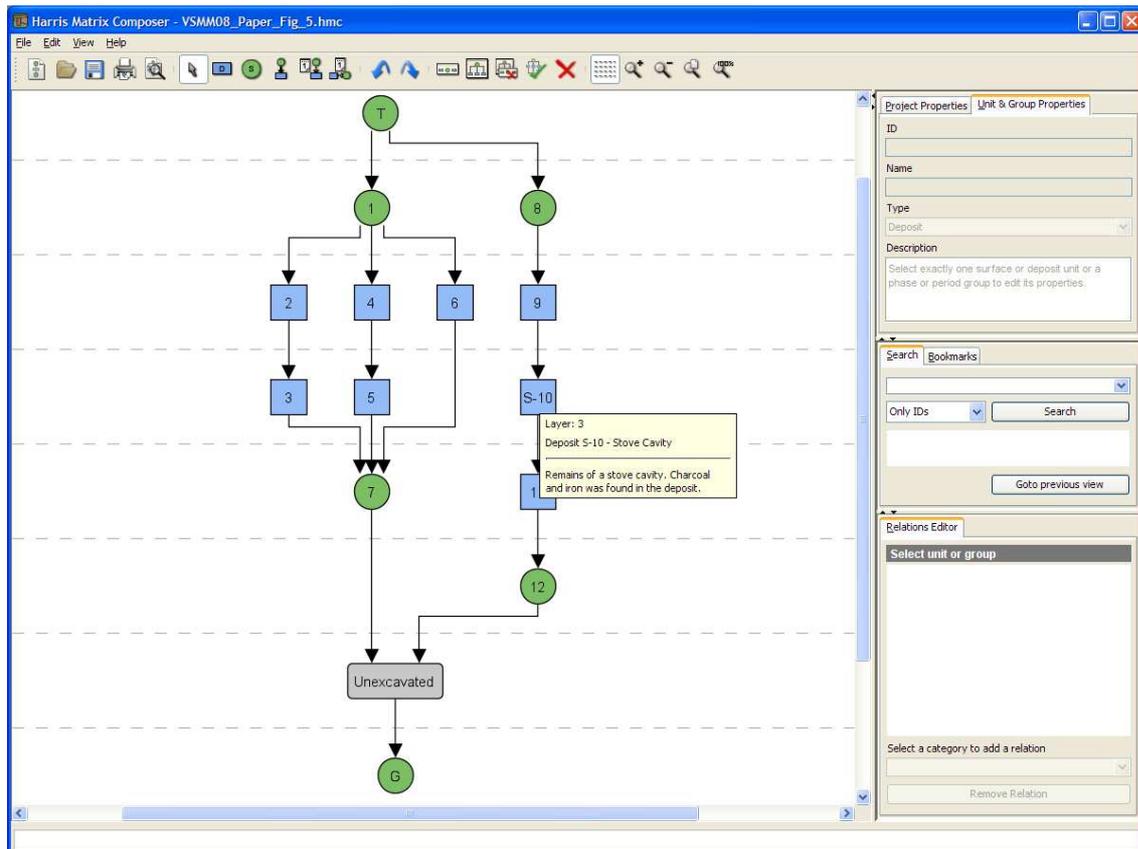


Fig. 7 – Properties set in the properties editor are shown in a pop-up balloon, when the mouse is moved over a unit.

The Relations Editor

This panel lists all relations of the selected unit, phase or period (see Fig. 8). It provides an additional view beside the graph structure in form of a list. Beside the relation “above” it shows also the relations “below”, which is defined implicitly, i.e. when A is set to be above B then B is implicitly set to be below A. In addition it also lists all temporal relations including “earlier” as complement to “later” and “contemporary”. If the selected unit belongs to a phase and/or period then they are also shown.

The relations editor provides an alternative way to set relations. For each relation category a unit can be chosen to establish the corresponding relation between the selected unit and the chosen one. The corresponding line is then immediately drawn in the graph editor. It is also possible to delete relations

in which case the corresponding line is removed. The selected unit can also be assigned to an existing phase or period by choosing it from the drop down list.

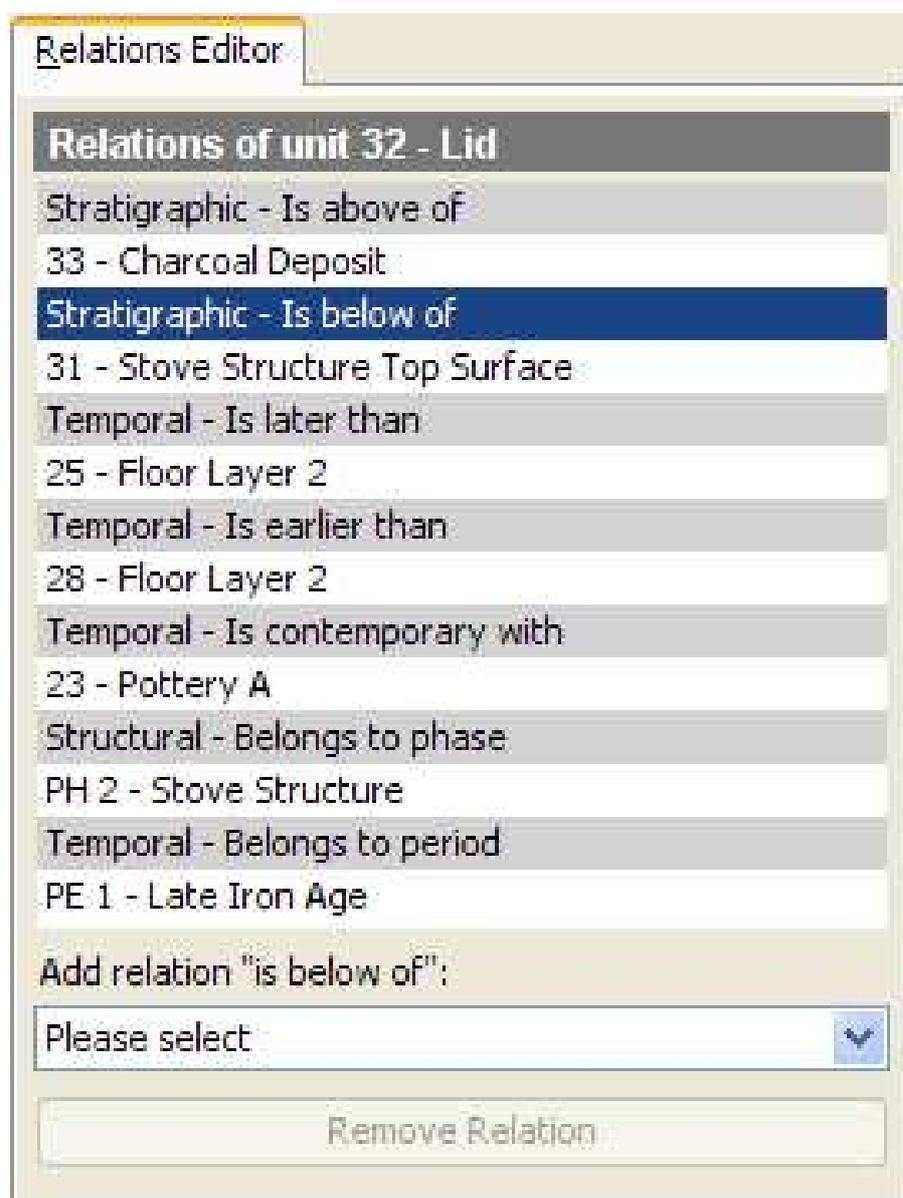


Fig. 8 – The relations editor showing all relations of the selected unit.

Conclusion

With the HMC a new tool for the composing and editing of a Harris Matrix has been introduced to the archaeological community. We are glad about all the positive feedback and the constructive comments we received so far. The strength of the HMC lies in its full compliance with the theory, which has been achieved in collaboration with its inventor Dr. E. C. Harris.

Another aspect is its usability, which was evaluated from the very beginning by successive user test on early prototypes. Further feedback of users and field trials will improve and extend the HMC so that

a reliable and robust tool emerges. We hope it will gain high acceptance in the archaeological community. We also think that it is very well suited for the training of students in courses and labs. If so, it will foster the practice of stratigraphic excavation.

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