Linking 2D Harris Matrix with 3D Stratigraphic Visualisations: An Integrated Approach to Archaeological Documentation

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ABSTRACT

This paper will present the first results of a new approach to recording and visualising archaeological excavations using integrated 3D and Harris Matrix data entry, query and visualisations tools.
Accurate records of stratigraphic sequences in an archaeological excavation are crucial for post-excavation analysis. Traditional recording techniques capture 2D or 2.5D surface plans of stratigraphic units. Relationships between units are recorded and the sequence is visualised as a 2D abstract model, the Harris Matrix. Several software tools have been developed to assist in this task, replacing earlier time-consuming and error-prone paper-based methods. Recent progress in photogrammetry and other 3D recording techniques has also made it possible to visualise excavated layers in a 3D space. Computer technology has thus developed to incorporate photogrammetric models, enabling archaeologists to view and analyse excavations within the 3D world in which they work.
A review of existing tools has shown that whilst each approach to visualising excavated layers has particular strengths, individually they do not provide a level of understanding that is required for a 'complete picture'. A computer generated Harris Matrix diagram is essential for understanding stratigraphic relationships, whilst a 3D model is extremely effective for the visual comparison of the form and structural relationships of these layers. We conclude that 2D abstract models and 3D views provide different, but complementary, benefits in the analysis of an archaeological excavation. For archaeologists to significantly benefit from both of these tools, we believe that linked 2D and 3D views should be available. This paper describes a first attempt to provide such linking.
Two tools providing suitable visualisations are the jnet graph tool and the Stratigraphic Visualisation Tool (STRAT). Jnet is a 2D Harris Matrix tool that allows the user to analyse stratigraphic relationships between layers and manipulate data. The STRAT tool is a 3D world in which archaeologists can navigate and explore in detail the layers of an excavation. The integration tool uses XML to communicate between jnet and STRAT providing a standard description method to facilitate the data exchange. XML is the native data format for jnet, so it provides seamless software mapping between the two tools. Import and export software incorporated within both STRAT and jnet transforms and stores this data in a structure suitable for exchange between the 2D (jnet) and 3D (STRAT) applications.
The result of this software solution is a flexible composite software tool allowing two different views of a site, which archaeologists can use to model, view and analyse their excavations more effectively. A test excavation was carried out in Sagalassos (Turkey) in the summer of 2004. After documenting and registering the stratigraphic data on site, it was entered into the new tool. Sections of a Harris Matrix, such as a particular trench, can be viewed to establish relationships between strata. Navigation in 3D within a trench permits viewing from all angles and replaying through the stratigraphic sequence. The results, presented in this paper show the high potential of this approach for future archaeological research.

1. INTRODUCTION

The idea that the features of an archaeological site are found in a stratified state, one layer or feature on top of the other, is of first importance concerning the investigation of sites by archaeological excavation. However, this stratigraphic data will disappear as the excavations proceed and therefore accurate visual records are needed in order to study the finds within their context and to allow for later reassessment if necessary. The EPOCH network develops a new state-of-the-art tool that can assist archaeologists in the systematic recording of their excavations.
A widely used archaeological representation, analysis and correlation of stratigraphic data employ a two-dimensional Harris Matrix approach (Harris, 1975/1989). However, this approach does not provide a 3D visualisation of an excavation site. In 3D, layers that are close to each other can be easily compared based on their physical attributes, thus providing more information to aid in the correlation of such layers. Archaeologists, however, would like to use both forms of visualisation therefore a combination of the two existing tools (jnet and STRAT) would prove ideal in order to view a site as either a Harris matrix graph or a 3D visualisation.
To solve this problem, software has been developed to interface the data structures of jnet and STRAT tools by graphically mapping their XML tags. This paper explains the mapping of the two tools by firstly providing a brief description of jnet and STRAT and then the Integration tools used to map them. Existing techniques within this area are also presented and the integration tools are evaluated by analysing the strengths and weaknesses of the solution. Finally an explanation is given as to how this integration software can be applied to archaeology.

2. A REVIEW OF 2D/3D VISUALISATION TOOLS AND INTEGRATION SOFTWARE

A review of 2D and 3D software tools plus integration techniques will be presented in this section in order to justify the need for the current research proposed within this paper.

Many applications have been undertaken concerning stratigraphic visualisation in 2D using the Harris Matrix. In 1990 Boast and Chapman (Boast and Chapman, 1991) created a Harris matrix generation program that could be integrated with other forms of data. They described a database schema that stored stratigraphic layers (contexts) in relation to each other, thus a significant time saving tool for archaeologists intensely analysing site records.

Herzog also developed a program using a Harris Matrix graph. Herzog's program produced a Harris Matrix automatically from all available chronological information. She stated that the possibility of being able to see the spatial correspondence between strata would allow for a more accurate configuration of the strata on a chronological graph (Herzog, 2001)

However, the above software is limited to 2D visualisations as opposed to the 3D environment in which archaeologists work. Research carried out by Koussoulakou and Stylianidis (Koussoulakou and Stylianidis, 1999). Recognised that visualisation in a 3D environment or a Geography Information System (GIS) with 3D capabilities made the process of establishing the relationships between finds in successive layers far easier. Moreover, they noticed that due to practical limitations that although archaeologists were recording data within a 3D environment, this data could only be represented in a 2D space. Koussoulakou and Stylianidis attempted to combine all the information available from the Toumba hill excavation in Thessaloniki, Greece into a 3D representation of the excavation site through the use of GIS and visualisation tools.

The above examples show evidence of research into 2D and 3D software systems, but there is no attempt to integrate 2D and 3D. However, integration software has been developed for other means such as Collins in 2002 (Collins *et al.*, 2002) In this research a framework was built for heterogeneous database access in which a library system (libSyD) was presented as a prototype software tool. This system used XML schemas as the data model for schema integration in order to facilitate querying and integration from various data sources. The concept behind this solution is very similar to that proposed in this paper for archaeologists, although it is applied to a different field.

This approach to data exchange was also implemented by Badard (Badard and Richard, 2001) in order to find a new solution for the updating of information for GIS's. Based on XML, it aimed to provide users with structured and more detailed information regarding evolution, hence making system integration easier. The research demonstrated that the use of XML in data exchanges was becoming commonplace in most GIS systems. Moreover, this type of integration did not have to be limited to geological software and could be used for other applications such as the integration of archaeological tools proposed in this paper.

3. JNET AND THE STRAT TOOL

Several tools exist to visualise archaeological data, two of which are the STRAT tool and jnet graph tool. The STRAT tool allows the user to view an archaeological site in 3D, whilst the jnet graph tool enables archaeological data to be viewed as 2D Harris Matrix. It should be noted that these tools give two totally different visual forms of an excavation site as separate applications. Archaeologists, however, wish to have the benefits of both forms of visualisation within one software system. Thus, this has led to a software mapping to integrate STRAT and jnet. The linking of these two tools enables archaeologists to view an excavation site either within a 3D world or as a Harris Matrix graph.

3.1 THE STRAT TOOL

The STRAT tool enables wide-ranging visualisation and manipulation plus the storage and querying of archaeological data. A variety of archaeological data, including building elements (features), artefacts, stratigraphy, plan/profile drawings and photographs can be entered or input into the tool (Figure 1).

The digital nature of the software allows complex querying, viewing, correlation and hypothesis testing to be carried out. A site can be viewed and navigated from any angle and position as close up or far away as required. 3D models of all aspects of a dig can also be represented, including: scanned buildings and building elements; artefacts; stratigraphy; hypothesised/reconstructed building elements and surveyed points. In addition, a variety of 2D information, such as: plan and profile drawings or polaroid photographs that are often recorded about a site can also be entered into the STRAT tool's local Database and visualised within system.

3.2 THE JNET GRAPH TOOL

Jnet developed by Ryan (Ryan, 2001) is based on a Model-view-controller (MVC) pattern shown in Figure 2. The GraphModel component stores a representation of the graph in memory and provides methods for layout, manipulation and editing. The Controller links the model with the view and routes messages between them. The view is represented

by Painter and Canvas objects. The Canvas is a Java 'interface', a generalised specification of object behaviour, which may be implemented in different specialised forms. Several specialised implementations of the Canvas interface may be plugged-in to render.
The graph in various formats either as part of a fully interactive display or as a stream of graphical commands depending on which version of the canvas is used. The Graph Store provides generalised behaviour for fetching and saving graphs or their component parts. Specialised implementations support local files plus local and remote database connections (using JDBC), and other remote stores using an XML serialisation of the data for transport over the intervening network.

3.3 SOFTWARE DESIGN

3.3.1 THE SOFTWARE MAPPING

XML (eXtensible Markup Language) has been chosen to map the above software tools, not only because this is the output format for jnet, but also because it provides structured information in order to make system integration easier. This method is implemented in a similar way to the exchange of information between geographical information system developed by (Bardard and Richard, 2001). XML organises data, which makes it perfect for the exchange of information between different software tools.

3.3.2 THE IMPORT AND EXPORT OF STRAT DATA

To facilitate the integration, software has been developed in c++, to firstly export information from the STRAT database as XML and secondly to allow the importation of an XML file into the STRAT database. A Similar tool was developed by (Collins *et al.*, 2002) to perform schema mappings from existing databases to an XML file. Due to the fact that jnet outputs data as XML in a Harris Matrix structure and the STRAT tool exports XML according to a data model (Figure 3), an XSLT mapping is therefore required to transform between the two structures. XML data output by jnet has to be transformed into a structure STRAT can recognise before it can be imported into STRATs local database for 3D visualisation.
Similarly, information from the STRAT tool database that is to be exported as XML, also has to be transformed into a structure suitable for jnet in order to be viewed in a Harris Matrix format. Both XML files output from the two tools are organised according to an XML schema (Figure 5). An XSLT transformation can then be applied to the schemas to map between the two XML files.
An import and export tool is required for both jnet and the STRAT tool. The import and export functionality is shown in Figures 4 and 5 below. Regarding the STRAT tool, the XSLT transformation between the STRAT schema and the jnet schema will be mapped using Mapforce to invoke an XSLT transformation. Figure 16, shows the schema mapping and how Mapforce will be used to provide an XSLT transformation for the schemas. This diagram shows not only shows how the XML output from the two tools is structured according to their specific schema, but also how Mapforce generates an XSL transformation to map the XSD files between the two tools, hence completing the integration. The XSLT transformation, plus the import and export tools for both STRAT and jnet provides full integration required for mapping between the two tools and hence visualising a site in both 3D or as a graph model.

3.3.3 IMPLEMENTATION OF THE INTEGRATION TOOLS

As mentioned above, the Integration tools comprise import and export software. The export software 'reads in' data from the database and exports this data as an XML file. The export tool is shown below (Figure 7). The data from the Sagalassos excavation database is loaded into the browser and then this data can be saved as an XML file.
The XML file produced from the Sagalassos database example loaded in Figure 7 is demonstrated in Figure 8.
The import tool performs an opposite operation to that of the export tool. Instead it reads an XML file in the above format and saves this data to the database, so the data can be visualised in 3D within the STRAT tool.
However, from the implementation undertaken so far to export the data from the STRAT tool as XML, it has become evident that there is not a straight mapping link between the two tools. This is due to the fact that both tools use different excavation information in order to generate their visualisations. This means that a similarity has to be found between the data forms in order to map the tools successfully.
The export tool has been created to output data from the STRAT tool as XML, so the next step is to 'streamline' or configure this data to export only data types that can be used by jnet to create a graph. This requires studying the data structures closely for both tools in order to find a mapping between them. This also has to be undertaken concerning the mapping of jnet to STRAT so the STRAT import tool is able to generate a 3D visualisation from the exportation of jnet data types that are suitable for STRAT.

4. ANALYSIS OF THE INTEGRATION SOLUTION

This section of the paper will discuss the strengths and weaknesses of each tool and how the integration software could help overcome the problems identified. Additionally, the integration software will also be discussed to establish the benefits of this software and also how this solution may have its own problems.

The 3D representation in the STRAT tool enables archaeologists to visualise an excavation site according to the environment in which they work. Moreover, in 3D, layers close to each other can be compared easily based on their physical attributes, thus providing more information to help in the correlation of the excavation layers. A disadvantage of this tool is that it does not provide a graph or Harris Matrix to show the layers in a tree view, which is very helpful for archaeologists.

The jnet tool, however, whilst only providing a 2D graph is very suitable to establish relationships between layers. Furthermore, this tool gives a Harris Matrix view of a site. As features are found in a stratigraphic state then this is considered very important, as the data will disappear due to the excavation procedure. The main problem with this software is that is does not show the site in a 3D space as mentioned above.

The two tools separately give two totally different views and have two totally different perspectives of a site. They also have different strengths and weaknesses that could be resolved by software mapping. Understandably, due to the nature of archaeology and the need to record as much accurate information as possible to model an excavation, archaeologists would benefit from both tools. However, this approach also has complications. The combination of tools is not easy due to the fact that both tools require different data formats. This is because they both produce a visualisation based on specific data requirements. Concerning the mapping of data, this could be problematic, as data would have to be accurate for both tools in order for the mapping to work successfully.

One of the strengths of this approach is that the integrated tool will use XML, a commonly available export format for databases. Moreover, it uses a commercially supported tool that allows users to graphically map between two schemas, which means that anyone could configure the mapping. Another significant benefit of using XML as a data mapping method is the interoperability between archaeological software. However, problems may arise during the XML data mapping, which may in turn affect the visualisation.

Regarding archaeologists, this tool provides significant benefits as it allows visualisation in the important Harris Matrix form, which is considered extremely useful. In addition, it also incorporates a 3D environment allowing the user to navigate freely within a 3D world that is modelled on the site. Used together these tools are able to compliment one another to give both a 3D model and a graph both related to the same excavation site.

5. ARCHAEOLOGICAL APPLICATION

From the analysis of past work, there has been no attempt to produce integration software to merge two existing archaeological modelling tools. Thus, this is the first attempt to enable archaeologists to have the benefit of both a 2D and 3D visualisation of an excavation site.

Both of these tools separately allow archaeologists to model excavation sites in either 2D or 3D, but they are not able to do this within the same application. The integration of these tools aims to solve this problem in order to provide archaeologists with an integrated system that will enable them to have the benefits of both forms of visualisation. In addition this software will provide a more flexible viewing environment for its users by giving them alternative ways to model a site based on what they need to analyse or indeed how they may prefer to analyse their data.

CONCLUSION

The software described within this paper integrates two tools namely: jnet and the STRAT tool providing the user with both a 3D view and or a graph structure of the data. The STRAT tool enables the user to visualise a site in 3D whilst jnet provides a graph model of an excavation site. By integrating these software tools by developing an Integration tool as described provides more flexibility not just in the visualisation of a site, but also for data entry purposes. This is a very useful integration tool for archaeologists as they benefit greatly from the option of both forms of visualisation. To extend this concept further, this approach can also be used to map legacy databases for either jnet or the STRAT tool.

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FIGURES

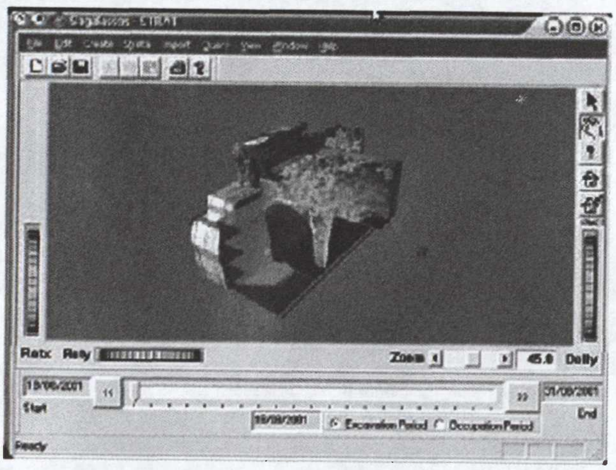

Fig. 1 – STRAT Tool.

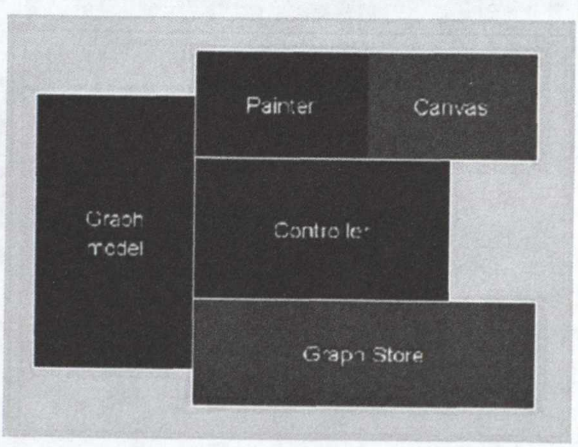

Fig. 2 – Basic jnet architecture.

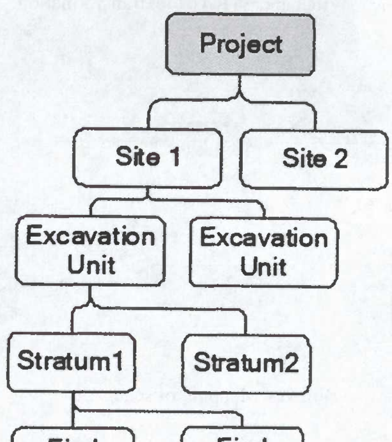

Fig. 3 – Archaeological data objects modelled in STRAT's memory.

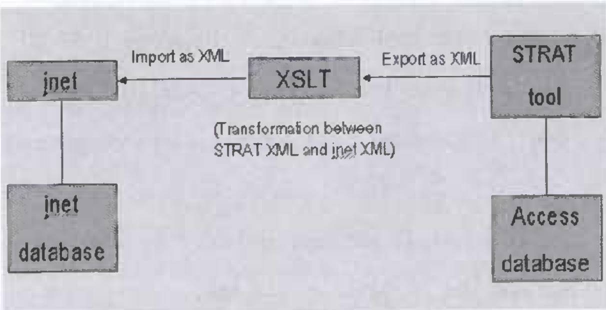

Fig. 4 – STRAT tool and jnet transformation.

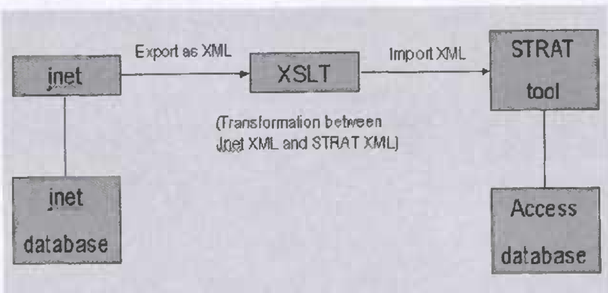

Fig. 5 – jnet and STRAT tool transformation.

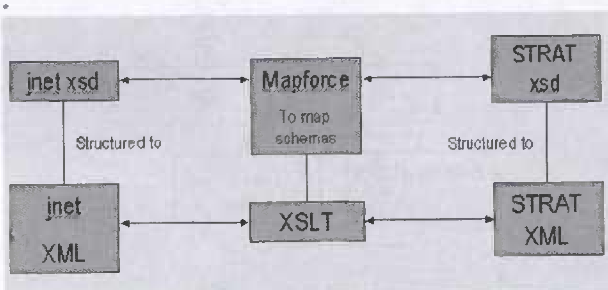

Fig. 6 – Mapping of schemas.

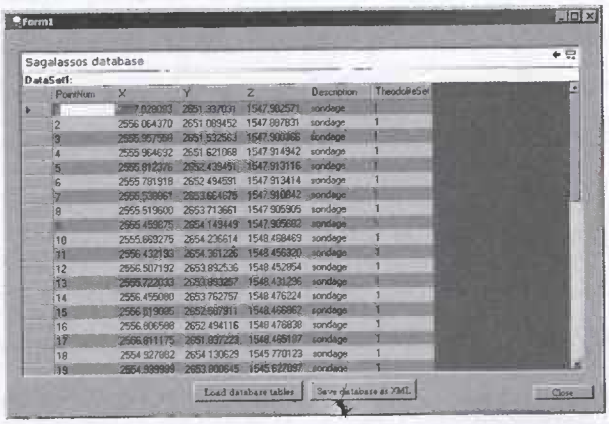

Fig. 7 – Export tool.


```
<?xml version="1.0" standalone="yes" ?>
- <DataSet1 xmlns="http://www.tempuri.org/DataSet1.xsd">
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    <ExcavationUnitID>1</ExcavationUnitID>
    <Length>5</Length>
    <Width>5</Width>
    <OffsetX>0</OffsetX>
    <OffsetY>0</OffsetY>
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  </ExcavationUnits>
- <ExcavationUnits>
    <ExcavationUnitID>2</ExcavationUnitID>
    <Length>5</Length>
    <Width>5</Width>
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    <SiteID>2</SiteID>
  </ExcavationUnits>
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    <Description>(nails, hooks, metal jewellery, figurines,...)</Description>
  </Materials>
- <Materials>
    <ID>4</ID>
    <Material_x0020_Name>bone</Material_x0020_Name>
    <Description>(animal bone, bone hairpins, spoons, ...)</Description>
  </Materials>
- <Materials>
    <ID>5</ID>
    <Material_x0020_Name>human bone</Material_x0020_Name>
  </Materials>
```


Fig. 8 – Information from the database saved as XML.