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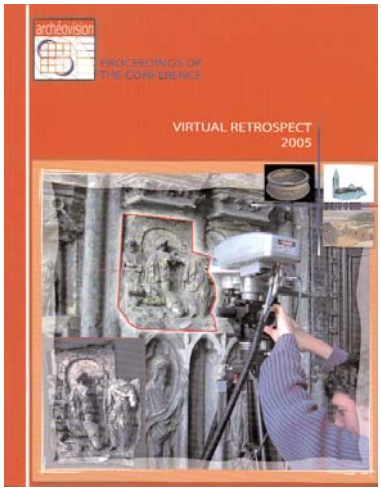

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DYNAMIC 3D VISUALISATION OF HARRIS MATRIX DATA

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Abstract : A method of 3D visualisation of archaeological sites combining 3D spatial representation of particular excavation units with complex symbolic representation of the sites based on the Harris Matrix model is presented. The 3D representation provides information about geographic and geometric properties of the units, while the matrix representation reveals temporal relationships between the units and layers. Dynamic creation of the 3D models provides a high level of flexibility allowing users to freely select data and adjust the method of visualisation.

Keywords : Virtual Reality — Archaeology — Harris Matrix — 3D Visualisation — Database Modelling.

1 Introduction

The Harris Matrix is a convenient and widely used method of symbolic modelling and analysis of stratigraphic data in archaeology. The Harris Matrix provides a representation of stratigraphic sequences in archaeological sites showing the temporal relationships between units, such as “earlier than”, “later than” and “contemporary”. However, the Harris Matrix representation does not convey information about geographic and geometric properties of the archaeological sites, layers and units.

Recently, a lot of research effort has been invested in 3D visualisation of archaeological data. 3D representation provides means of displaying exact positioning and geometry of sites and units within the sites along with their additional attributes. However, realistic 3D visualisation, although appealing, may not be as convenient as expected in real applications because it reveals problems immanently associated with 3D representation, such as occlusions, layer invisibility, and difficult representation of highly different scales. Most importantly, it does not convey the temporal information about components.

In this paper, we propose a method that combines the geometric 3D representation of units within archaeological sites with symbolic representation of relationships between the units by the use of the Harris Matrix model. Dynamic creation of the 3D models allows users to freely select the data and adjust the mode of visualisation. The proposed method is based on the X-VR approach, which combines two techniques: database modelling of virtual worlds and dynamic modelling of virtual scenes.

In the proposed approach, a rich database model is used to represent stratigraphic data. This allows easily selecting ranges and types of data for visualisation. Using a simple web-based data management application, several archaeologists can easily share the same dataset, enabling group work. Using a database system for data storage instantly gives numerous benefits, which, among others, include efficient data representation, convenient retrieval of data, transactional processing and verification of data integrity constraints (possible values, relationships, etc.). Changes made in the database may be almost instantaneously visible to all users. Dynamic generation of the 3D visualisation scenes allows users to formulate queries to the database to select units or layers with particular properties, include or exclude particular classes of objects, and adjust the method of visualisation.

The 3D representation of Harris Matrix diagrams extends the traditional 2D approach by putting the diagrams into a geographical context, adding geometrical properties, and also increasing information capacity. Additional information, such as unit type, soil properties, inclusions, links to finds etc., can be easily visualised together with standard Harris Matrix data. Dynamism allows users to easily refine, adjust and customize the diagrams in an interactive process.

A prototype of the X-VR based 3D Harris Matrix visualisation system has been developed. The prototype can work as a standalone tool as well as a service on the Internet. The latter is possible because the 3D diagrams can be displayed using standard VRML plug-ins to Internet browsers without installing any specific software. The system has been tested on data from excavations in Dziekanowice – Site 22 (Wielkopolska, Poland).

The remainder of this paper is organized as follows. In Section 2, works related to visualisation of Harris Matrix data and 3D geographical data are discussed. In Section 3, the concept of 3D visualisation of Harris Matrix data is presented. Section 4 provides a short overview of the X-VR approach. Section 5 describes in detail the architecture and implementation of our system. In Section 6, the data used for visualisation is briefly described. In Section 7, examples of Harris Matrix visualisations are presented. Finally, Section 8 concludes the paper and indicates future research directions.

2 Related works

2.1 Harris Matrix visualisations

Understanding the way in which deposits have accumulated to form layers on an archaeological site requires awareness of stratigraphy. The Harris Matrix is a tool used to assist in the examination and interpretation of the stratigraphy on archaeological sites. Stratigraphy does not define exact chronology, but only relative chronology. Visualisation of Harris Matrix has a form of a diagram that depicts archaeological units, layers, structures and features, with their relationships and sequence. In the form of a flow-chart going from the latest (top) to the earliest (bottom), the matrix has lines linking boxes, inside which are written the context numbers of the units which they represent. These help in the process of recording, clarifying and understanding the build-up of deposits which an excavation encounters.

Harris Matrix visualisation is a convenient form of graphical representation of stratigraphy suitable for most archaeologists. Edward C. Harris' sentence defines the idea of project: "The Matrix will probably prove to be one of the most useful and enduring contributions which historical archaeology has made to the profession in general" [1].

The classical 2D visualisation of the Harris Matrix can illustrate the vertical positions of units. In addition, each unit is described by a number of attributes, such as soil properties, inclusions, interpretation, grid or geographical location – important horizontal position, links to drawings, photography finds, and samples. However, these characteristics are not included in traditional diagrams, because of the limited space for presentation. For the collection, analysis and presentation of these descriptive attributes archaeologists use external databases.

Computer applications for building Harris Matrices date back to the 1970's. Most popular are non-profit projects made for and by archaeologists: ArchEd [2], WinBASP [3] and Stratify [4]. The Bonn Archaeological Software Package (BASP) has been developed since 1973. The last version includes functions for seriation, clustering, correspondence analysis, and mapping tools for archaeologists. The popular ArchEd contains an automatic drawing feature but users can modify the view of diagrams. Stratify supports interactive and automatic checks in order to detect inconsistent, missing, or contradictory relationships. One of the best commercial applications is MatrixBuilder made by Proleg [5]. MatrixBuilder automatically generates a fully customisable visualisation. Units are positioned taking into account stratigraphy and chronologies.

Relatively little innovation has been visible in this domain during the last decade. Presented applications work on the most popular Windows platform, unfortunately not useful for mobile PDA's. Only the British jnet [6] system is designed to support collaborative working in a mobile wireless networked environment, demonstrating the potential of using handheld devices on-site to support real-time data collection.

With the help of specialised software it is possible to relate stratigraphical data. Applications usually store data of the units and their stratigraphic relationships in internal databases and support interactive and automatic checks in order to detect inconsistent, missing, or contradictory relationships.

2.2 Geographical information systems

Archaeology is strongly linked to geography. Geographic variables have a strong influence on human behaviour, and this influence was also significant in the past. Geography also influences the degree of exposure of archaeological sites and the impacts that they faced from human activity and natural forces. Geographic analysis and modelling provide answers to a variety of questions and help archaeologists in the research and management of resources.

Geographic Information System (GIS) is a technology that links geographic data (where things are) with descriptive data (what things are). This technology makes it possible to manage and analyse the data from a geographic perspective and then display the resulting geographic information [7].

Typical GIS systems are able to dynamically visualise the geographical data in form of virtual 2D maps. These maps use layers for presenting data. Each layer represents a different type of information and the sets of layers visualise how it all interrelates. In reality, most of the geographic data has a third dimension – the height component. Therefore, recently 3D visualisation is also being introduced to GIS packages. This has been made possible by significant progress in both software and hardware performance.

For example, the Environmental Systems Research Institute, Inc. (ESRI) [8] is one of the major providers of GIS solutions. One of their products – ArcGIS 3D Analyst together with ArcGlobe application [9] makes it possible to analyse and visualise surface data in 3D. By using ArcGIS 3D Analyst, it is possible to view a surface from multiple viewpoints, query a surface, determine what is visible from a selected location on a surface and create realistic perspective images. The ArcGlobe allows visualising, from local or global perspective, large sets of three-dimensional geographic data as data layers on a three-dimensional globe representation.

Modern GIS systems provide means of 3D visualisation of surface data, including elevation grids, roads, rivers, buildings, trees and other landscape objects. 3D GIS systems are a convenient solution for presenting geographical data, but since no temporal relationships between objects can be presented they are not sufficient for the visualisation of archaeological sites.

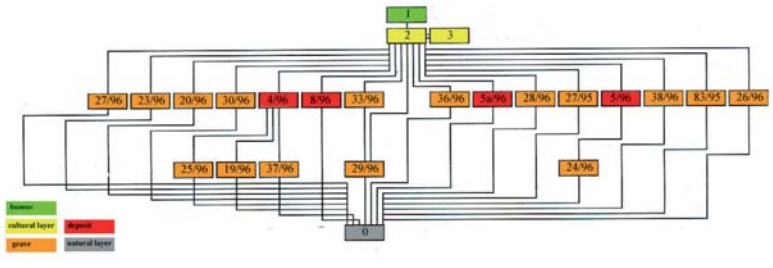

Fig. 1: Visualisation of the Harris Matrix created with Stratify.

3 3D Visualisation of the Harris Matrix

Classic Harris Matrix applications provide 2D data visualisation. A typical example of such visualisation is presented in Fig. 1. A 2D Harris Matrix diagram allows archaeologists to see the stratigraphic sequences of complex sites. Topographical localisation of single units is presented on separate plans and in databases.

In the proposed approach, a 3D Harris Matrix visualisation is used. The 3D Harris Matrix integrates vertical stratigraphy with horizontal topographical localisation of units in one complex visualisation. Visualisations are created for datasets stored in a database. The data may be entered into the database directly during the excavation process or recorded first on context recording sheets. The data consists of unit numbers, types, relationships (earlier than, later than, contemporary with, equal to), provisional periods, groups, grid squares, and coordinates or GIS positions.

The 3D Harris Matrix visualisation is created dynamically for each user request – specifying the selection of data and the method of visualisation to be used. To enable such dynamic creation of virtual scenes the X-VR approach has been used.

4 The X-VR approach

Existing standards for building 3D applications on the Internet, such as VRML and X3D, provide methods for describing contents of virtual scenes. In their current form, they make it possible to build only passive 3D systems, i.e. systems where the 3D technology is employed to visualize pre-designed virtual environments in a three-dimensional way. This enables the use of VRML for presenting architectural design, artistic models, and simple animations, but prevents it from being used in more advanced applications.

To make it possible to build active 3D systems on the Internet, the X-VR approach has been developed. In the X-VR approach, instead of passive virtual scenes, which act as 3D images or 3D movies, it is possible to build dynamic interactive data- driven applications. Two new techniques are used in the X-VR approach: dynamic modelling of virtual scenes, which provides the prerequisite infrastructure to build active 3D applications, and database modelling of virtual worlds, which enables the building of advanced database models of virtual environments.

Dynamic modelling of virtual scenes is accomplished by the use of X-VRML – a novel high-level XML-based modelling language [10][11]. The X-VRML language provides means of parameterization of all elements of dynamically generated virtual scenes – the contents, the visualisation methods, and the structure. X-VRML offers programming concepts known from procedural languages, object-oriented techniques, and convenient methods of accessing databases. The data retrieved from a database can affect all aspects of the dynamically created virtual scenes.

For database modelling of virtual worlds, a method called X-VRDB has been proposed [12]. The method consists in dividing a virtual world model into four distinct elements – the virtual world data, the virtual world structure and visualisation method, the virtual scene models, and the virtual scenes. Each of these elements can be separately modelled in a database.

In the system presented, the Harris Matrix data constitute virtual world data and are modelled in a database. Modelling VR data in a database enables efficient management of large amounts of data, provides powerful selection capabilities and enables continuous updating by multiple users.

5 System architecture

The overall architecture of the implemented system is presented in figure 2. The system consists of two main architectural components: data management subsystem and data visualisation subsystem. The database – shared by the subsystems – stores all excavation information, which includes data describing units (name, class, type, geographic coordinates, etc.) and relations between the units.

The data management subsystem provides means for managing the excavation data in the database. It makes it possible to browse and edit the contents of the database as well as to enter data manually or load data from external sources. The data management tools are implemented as a web application accessible through a standard web browser.

The visualisation of the excavation site is performed by the data visualisation subsystem. The visualisations are dynamically generated based on the database contents – the excavation information, the visualisation models and parameters provided by a user. The generated visualisation of the excavation site is sent to the user and displayed in a standard web browser equipped with a VRML plug-in.

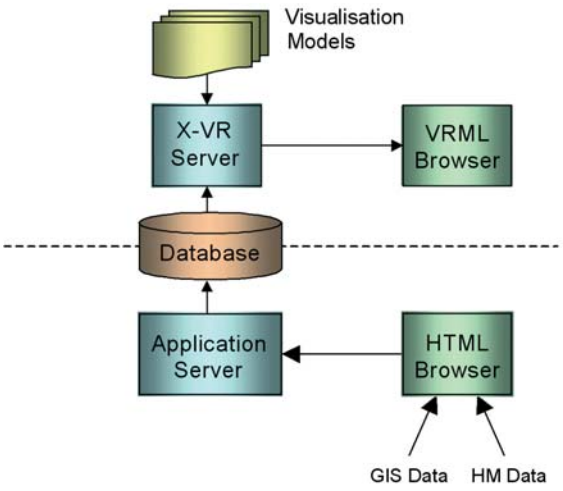

Fig. 2: System architecture.

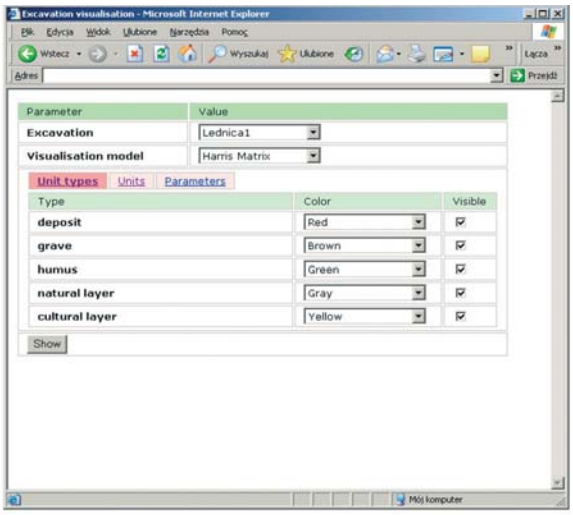

Fig. 3: Model parameterisation form.

The use of different visualisation models and model parameterisation enables different visualisations of the same content. A user may also create different visualisations by selecting different subsets of data.

6 Archaeological data

For testing the 3D Harris Matrix visualisation system, datasets from archaeological research work that took place on the site of Dziekanowice in north-central Poland have been used. The town of Dziekanowice is located about 35 kilometres north-west of Poznan. Archaeological research at Dziekanowice focuses on the study of a Polish early medieval cemetery. The visualisation has been performed on data from site Dziekanowice 22, excavation III explored in 1996 by Jacek Wrzesi ski (Museum of the First Piasts at Lednica/Poland) [13]. The structure of studied data contains information about geographical locations of the single units, unit types and numbers and stratigraphical relations.

Stratigraphic situation was not complicated. Excavations uncovered three layers: humus, human activity layer with early medieval deposits and human burials, natural layer (see fig. 1). A total number of 14 inhumation burials and 4 deposits were excavated in a previously known part of early medieval cemetery. Also, there were located two human inhumations uncovered in 1995 – grave 27/95 and grave 83/95. The majority of the burials are dated between 11th and 13th century. Deposits are dated between 11th and 12th century. No buildings were found in association with the cemetery. Excavation recovered from the burials several artefacts: iron knives, coins and jewellery.

7 Visualisation examples

To demonstrate the concept of 3D visualisation of Harris Matrix data, two visualisation models have been developed : the 3D spatial visualisation model and the 3D Harris Matrix visualisation model. Each of these models is parameterized allowing users to select the data and adjust the method of visualisation. In the following sections, the parameterisation process and examples of visualisations generated with the models are presented.

7.1 Visualisation parameters

The 3D Harris Matrix visualisation is parameterised, allowing users to select the visualisation model, the dataset to be used and the values of model parameters. The parameterisation is performed by the use of a web form as presented in Fig. 3.

After entering the visualisation parameters the user may press the Show button, which submits the data to the X-VR server and causes dynamic generation of a 3D model.

7.2 3D spatial visualisation

In figure 4 a 3D visualisation generated with the 3D spatial visualisation model is presented. The visualisation is based on the same dataset as presented in figure 1. In the spatial visualisation, each unit is visualised by default as a small cylinder placed in the exact location where the unit was found in the ground. The centre of each cylinder is located in the centre of the corresponding unit. The vertical locations and the heights of cylinders correspond to the Z coordinates of the units. The colours of cylinders correspond to the types of the objects they represent. Assignment of colours to types of objects may be changed by a user by selecting options in the parameterisation web form.

Displaying only the centres of the units instead the real units' shapes or bounding boxes makes the visualisation more lucid, especially in excavations such as graves, where units are discovered very close to or even intersecting each other. Importantly, this representation is close to conventional documentation methods used by archaeologists to document excavations.

A user may freely navigate in the 3D scene moving the viewpoint, rotating, and zooming in and out. The image visible on the screen changes depending on the selected viewpoint. The user may select the best viewpoint to observe particular elements of interest.

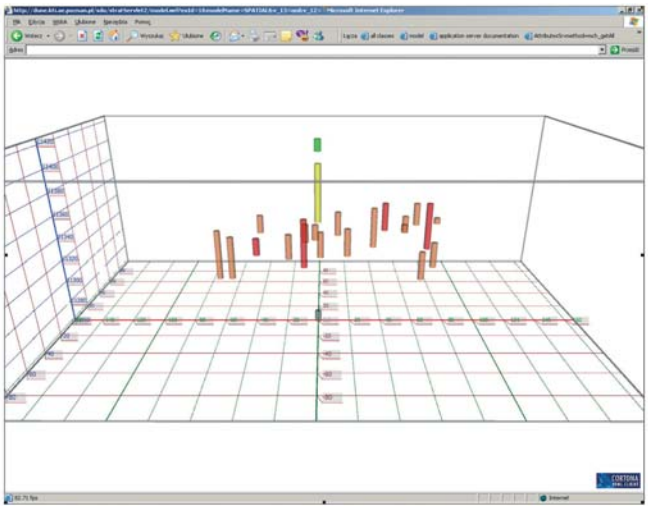

Fig. 4: Basic 3D visualisation of all units.

Clicking on a cylinder allows a user to turn on/off additional information about the corresponding unit. After the first click, the name of the unit is displayed as a label attached to the cylinder. After the second click, the unit's position and vertical size are projected on the X, Y, Z axes (see fig. 5). After the third click, the real size of the unit is displayed as a bounding box (fig. 6).
Moreover, in each state, a user may display an additional 2D side-window containing detailed information about a unit, by placing the mouse over the corresponding cylinder (see fig. 5).

7.3 3D Harris Matrix visualisation

The 3D Harris Matrix visualisation combines geographical and geometrical properties of the finds with symbolic temporal relationships represented by the Harris Matrix graph.

In this visualisation, the X and Y coordinates of the units remain the same, while the meaning of the Z coordinate changes. The Z coordinate no longer corresponds to the depth

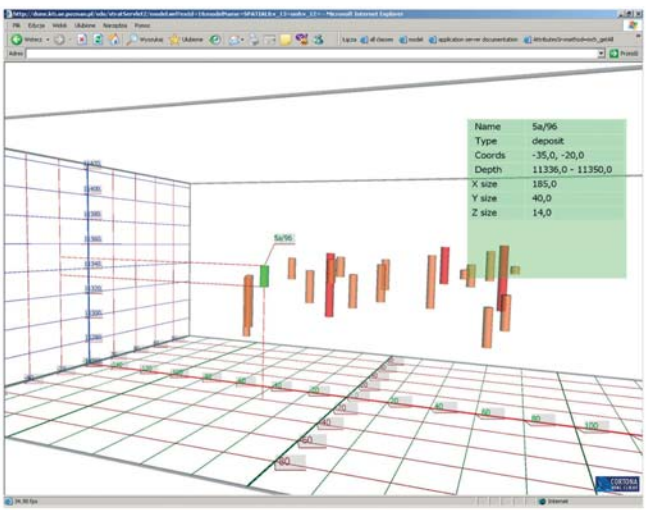

Fig. 5: Detailed layer properites.

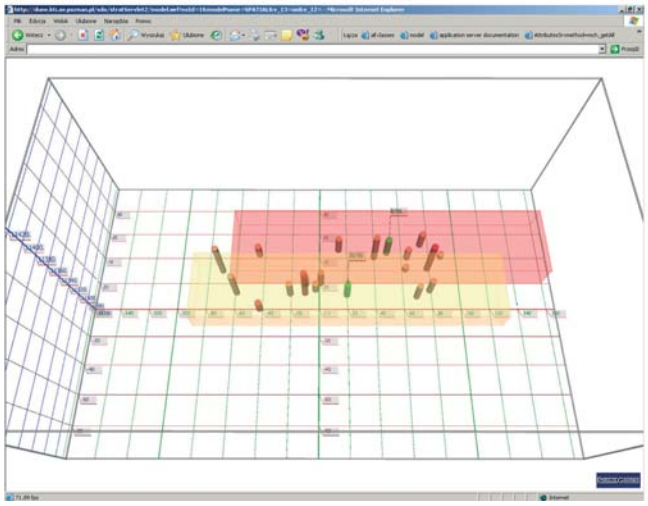

Fig. 6: Sizes of layers displayed as bounding boxes.

of the unit but now it corresponds to the vertical position of the unit in the Harris Matrix. An example of 3D Harris Matrix visualisation is presented in figure 7. Connections between the units representing the temporal relations in the Harris Matrix are presented as lines connecting cylinders.
In this visualisation, the height of the cylinders has been unified. In addition to layers visible in previous examples, three additional layers have been included: humus (green), cultural layer (yellow) and natural layer (grey). Two of the units are selected and their labels and geometrical positions are shown in the 3D scene.
An alternative version of visualisation can be achieved by changing one of the model parameters. As a result, a similar 3D scene is generated, but the sizes of cylinders in the Z direction reflect the real sizes of the archaeological units they represent. The resulting scene is presented in figure 8.

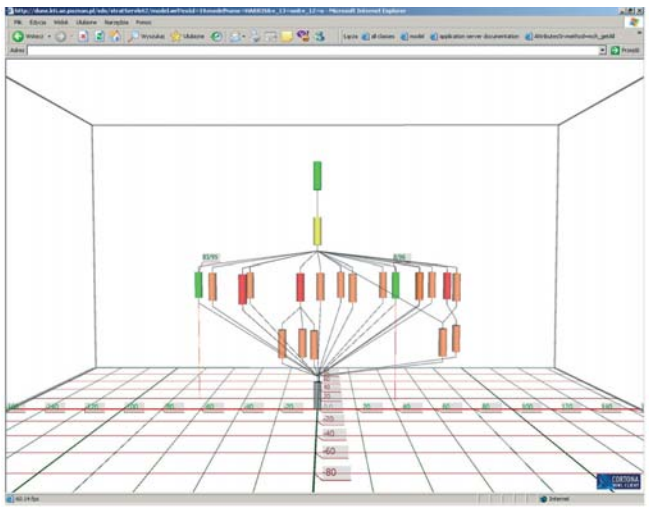

Fig. 7: 3D Harris Matrix visualisation – units with uniform heights.

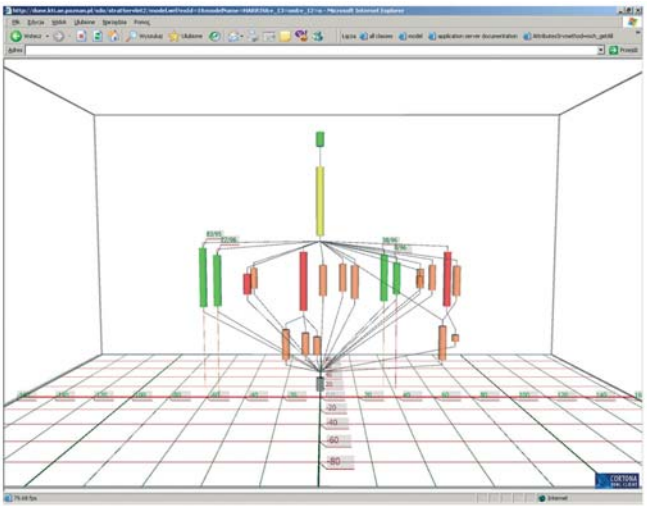

Fig. 8: 3D Harris Matrix visualisation – units with real heights.

8 Conclusions

In this paper a method of visualisation of archaeological sites combining real geometric properties of units with symbolic representation of relationships between the units has been presented. The method has been tested on a dataset coming from a real archaeological excavation site.

The achieved results prove that the method can be successfully used for the visualisation of archaeological data. On the one hand 3D representation clearly provides an added value as it allows us to study the spatial relationships between the units not conveyed in traditional Harris Matrix diagrams. On the other hand, disadvantages associated with realistic 3D visualisations have been eliminated by symbolic representation of the units, and the visualisation has been enhanced by demonstrating temporal relationships between the units.

The solution based on the dynamic modelling approach allows users to select the data to be visualized – either by providing some geometrical or temporal constraints, or by selecting particular units of interest. Users may also modify the visualisation method and associate features of the units to visual properties of their geometrical representations.

In the future, we would like to extend the system to include information about the exact shapes of units instead of the simple bounding boxes. Also, possibility of including additional information about the units will be investigated.

The perfect complete framework for field archaeologists should allow them to create real-time digital modelling of the excavation, present all descriptive data, especially stratigraphy in a 3D form (units relative-time calendar and real geographical locations) and optionally hyperlinks toplans, finds, photos, samples etc. The stratigraphy of archaeological sites with units situated in a spatial model of the terrain will become more understandable for more people, especially for non-archaeologists.

Acknowledgements

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Bibliography

[1] Harris, E. C. (1998): 25 Years of the Harris Matrix, Newsletter of the Society of Historical Archaeology, History of the Harris Matrix reprinted at http://www.harrismatrix.com.

[2] Mutzel P., Reitgruber B. and Schuhmacher B. ArchEd (2001): “an Interactive Tool for Visualizing Harris Matrices”, Archaologie und Computer, Workshop 6. Forschungsgesellschaft Wiener Stadtarchaologie , http://www.ads.tuwien.ac.at/ArchEd/.

[3] The Bonn Archaeological Software Package (BASP), product website, http://www.uni-koeln.de/~al001/basp.html

[4] Stratify, product website, http://www.stratify.org/.

[5] Proleg, company website, http://www.proleg.com/.

[6] Ryan, N. (2001): “Jnet a successor to gnet”, Archaologie und Computer, Workshop 6. Forschungsgesellschaft Wiener Stadtarchaologie (November 2001).

[7] An ESRI® White Paper, Geography Matters™ (September 2002), http://www.gis.com/whatisgis/geographymatters.pdf.

[8] Environmental Systems Research Institute, Inc. (ESRI), company website, http://www.esri.com/.

[9] ArcGIS 3D Analyst, product website, http://www.esri.com/software/arcgis/extensions/3danalyst/.

[10] Walczak, K. and W. Cellary (2003): “X-VRML for Advanced Virtual Reality Applications”, IEEE Computer, Volume 36, Nr 3, IEEE Computer Society Press, (March), 89-92.

[11] Walczak, K. and W. Cellary (2002): “Building Database Applications of Virtual Reality with X-VRML”, Proc. of the 7th International Conference on 3D Web Technology – Web3D - 2002, Tempe, Arizona, USA; ACM Publisher, (February), 111-120.

[12] Walczak, K. and W. Cellary (2003): “Modeling Virtual Worlds in Databases”, Information Processing Letters, Volume 88, Elsevier B.V., 67-72.

[13] Museum of the First Piasts at Lednica, http://www.lednicamuzeum.pl