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Discourse on the Use of a 3D Model as a Record of Excavation

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I believe that in the near future we will begin to record excavations as 3D computer models using new digital recording tools. This paper will consider some of the methodological issues, new protocols and software tools that will be neccessary in order to construct excavation records in 3D. I will then explore some new techniques and novel applications that working with such 3D models will permit.

Keywords: 3D model, excavation, recording.

1. Introduction

This paper aims to start us thinking about the way we will record excavations in the near future and, importantly, about some of the issues we must first address to get to that point.

It is now more than 35 years since CAA formed to promote and facilitate the use of computers in Archaeology and yet (despite 3D laser scanning becoming more popular in recent years) excavations are still almost exclusively recorded by drawing in 2D. It is my belief that the biggest impact of computing on archaeology is yet to be felt. It will be when we routinely record excavations in the form of 3D models.

While the use of 3D models to record excavations has been proposed by a handful of authors (AVERN, 2001a, 2001b; HARRIS, 2002; DONEUS *et al*., 2003; BARCELÓ *et al*., 2004; TSCHAUNER *et al.,* 2007), it is still a novel topic requiring considerable development. This paper will begin by exploring the likely form such new records will take in order that we may then consider some of the issues and difficulties which will be faced when we attempt to construct such 3D models.

I will then consider software tools which will be required for working with the excavation models, the benefits that working with such models will confer and, finally, some novel applications that might be realised given that we will be working with a digital 3D model.

2. The Excavation record

I expect that the future excavation record will consist of 2 parts. The first would be a 3D model which exactly replicates the archaeology that has been removed. Therefore, it will be made up of many discrete volumes (representing positive contexts), surfaces (representing negative contexts) and models of finds (inserted into the model as they are processed) (figure 1).

The second part will consist of the various site databases containing text data, photographs, etc. for each context and find. A link from each context in the model must be established to each of these database entries.

As we disassemble the site into its elements by single context excavation, we would record and store each of these contexts individually. However, the 3D model would simultaneously display as many individual shape files as we choose, to enable us to visualize groupings, spatial arrangements, different phases of the site development or, indeed, the whole site complex in its entirety.

However before we reach this point in the 3D excavation recording we must address 2 areas of

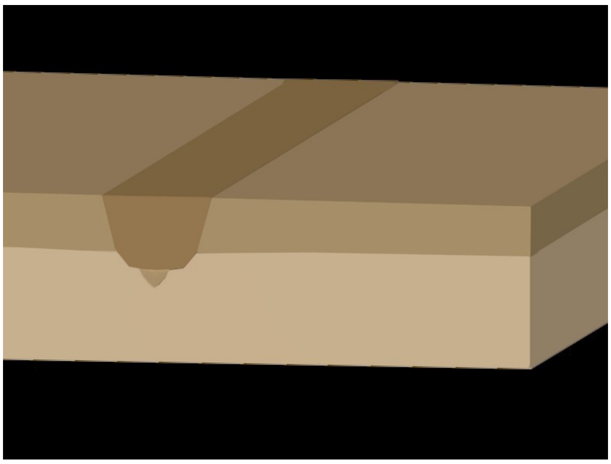

Figure 1: *3D model of a hypothetical excavation displaying 2 horizontal deposits, a ditch and a trace of an earlier ditch. This model is used throughout the paper and was created using Autodesk 3ds Max.*

development; the acquisition of 3D surface data and the construction of entities in our model from these surface data.

2.1. Acquisition of 3D surface data

The single significant breakthrough which will permit recording by 3D model will be the appearance of new scanning tools which I am confident will come to market in the next decade. Unlike terrestrial laser scanners and photogrammetry, these new tools will give us a much more practical means of recording context surfaces in 3D. They will record more accurately and much more rapidly than hand drawing and, I would argue, than the other digital methods just mentioned.

Text descriptions and commentary that are normally recorded on context sheets will still be necessary, of course, as will photographs. These will be stored in databases and linked to the appropriate context along with all other pertinent data.

2.2. Constructing the 3D excavation model

When recording in 2D we are usually only concerned with the outline or limits of contexts. Recording in 3D with these new tools we will, obviously, be recording entire surfaces of contexts. There are still a number of obstacles to be overcome before we can do this, even with new recording tools.

The recording of the surface of a context will have to be performed in 2 parts. Any scan of the surface will go beyond the extent of the context we want to record, so we will also need a polygon which represents the edge of the context that can be used as a mask to crop the original scan to define our surface record. If we are recording a negative context, this cropped surface becomes the end record but if we are recording a positive context, further steps are required.

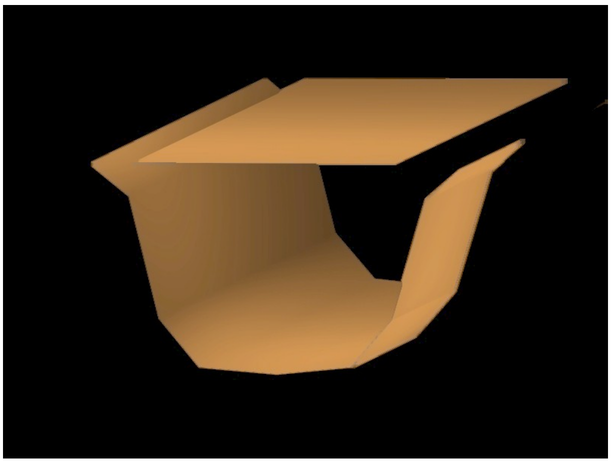

Figure 2: *Surfaces which define the volume of the fill of the later trench in our model. The top surface is scanned before the fill is removed. The lower surface is scanned when fill has been excavated and demonstrates how the exact edge where the 2 surfaces should theoretically have met is lost through overcutting.*

We will need algorithms for turning 2 or more scanned surfaces into a "watertight" 3D volume representing a positive context. We can expect that the process of matching top surfaces of features to their side and lower surfaces can, at best, only be semi-automated and will rely on at least some user input. This will be necessary since "overcutting" of contexts, "freshening" of edges, and the change in the context boundaries through normal wear and tear that can happen to the terrain between the exposure of a context and its excavation will create misalignments between edges of scans which should, in theory, meet (figure 2).

We will also need protocols to allow single surfaces to have multiple identities. Clearly, a surface which represents a cut feature will have a second identity as the lower surface of the fill of that cut. However, we can expect to encounter surfaces with much more complex multiple and partial identities (figure 3).

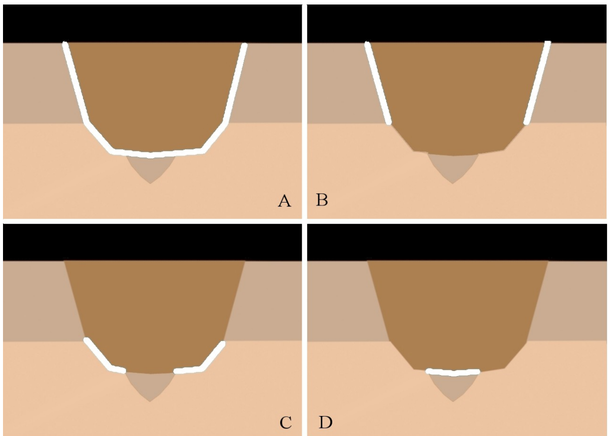

Figure 3: *Cross-section of our model illustrating multiple and partial identities of surfaces. A – surface of the cut of the later trench, which is also the lower surface of the fill of the trench; B – part of the previous surface shared with the upper deposit; C – part of the surface of the cut shared with the lower deposit; D – part of the surface of the cut shared with the fill of the earlier cut.*

It will be interesting to see how practical applications of this technology shape recording protocols. I imagine that we will make our initial records (the scanned surfaces) of the lower surface of a context. That is, once a layer is removed we will scan the entire surface it reveals (even though it may reveal more than one context), to avoid any deterioration of that surface with time as it is walked on, is troweled back, etc., etc. This single scanned surface will thus represent (and probably be filed as) the entire lower surface of the removed context rather than the contexts we are actually scanning.

When we come to constructing models from database files of surfaces, we will frequently need to use only portions of these scans of the higher (later) surfaces, as shown in figure 4 where the surface that bounds the upper deposit (outlined in white in A) is constructed from parts of the scans shown in white in B, C and D.

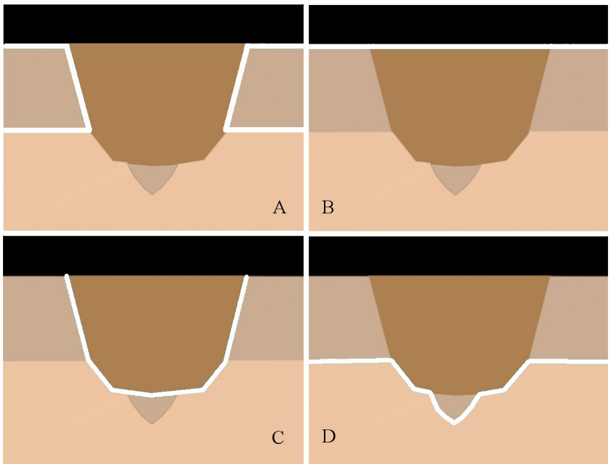

Figure 4: *Scanned surfaces which contribute to the construction of the model of the upper deposit. A – the surface model of the upper deposit, constructed from portions of the scans displayed in B, C and D.*

The protocols allowing for multiple identities of these surfaces should also be the means of creating and conserving vertical or chronological links between touching contexts. This will become vital to phasing (discussed later).

Very importantly, the utility of the composite excavation record (3D model plus databases) will depend on the integration between the model and the databases. We will need simple "devices" or protocols embedded in the recording routines of all data types (graphical, textual, photographic) to enforce the creation of all necessary links between the 3D model and databases at the time that the records are created.

3. Using the 3D excavation model

The 3D model would be a graphical interface through which we access any data about the excavation. It can act as a progress report for the excavator, an analytical tool for supervisor, as a convenient agent for drawing all the data together in an archive, and as a simple interface for distributing the results of the excavation online. Depositing the finished result with a regional authority could see it incorporated into a larger regional GIS of archaeology.

By clicking your mouse on a context we would call up a list of all files in all databases which pertain to this context. While this feature exploits simple embedded links, there are two very important tools which should be developed and implemented in software for use with the 3D model;

3.1. Translucency

Control over the translucency of each individual context will form a powerful tool for visualisation and analysis of the excavation. Partial translucency in all contexts will allow us to see all the contexts simultaneously (figure 5). We could leave finds, or classes of finds, fully opaque in order to see their distribution withing the site.

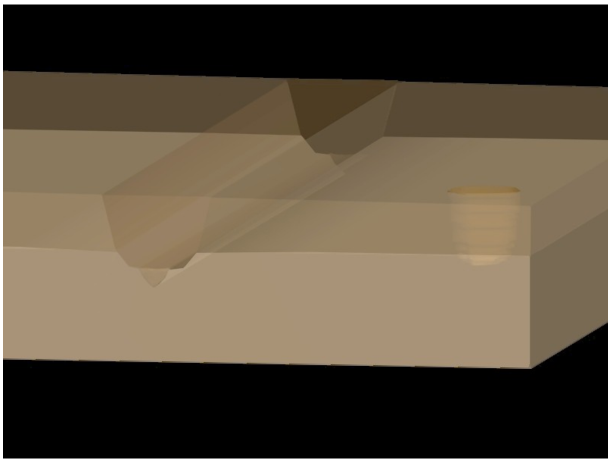

Figure 5: *Model of the excavation where partial transparency has been introduced in the more recent contexts enabling a view of all contexts in relation to each other.*

Control over translucency of individual contexts would also allow us to virtually "re-excavate" the site by making contexts fully translucent in the reverse order of the site formation.

3.2. Vertical "exploded view" of the model for Phasing

The Harris Matrix has been an indispensible tool for analysing excavations for decades but 3D models may make it redundant. The Harris Matrix is, after all, a scheme to simplify the visualisation of vertical relationships between contexts by ignoring their volumetric and spatial data. We could achieve a similar result by vertically "separating" the finished 3D model into its constituents (figure 6). The ability to adjust the vertical displacement of each context then becomes a tool to allow us to "phase" the excavation.

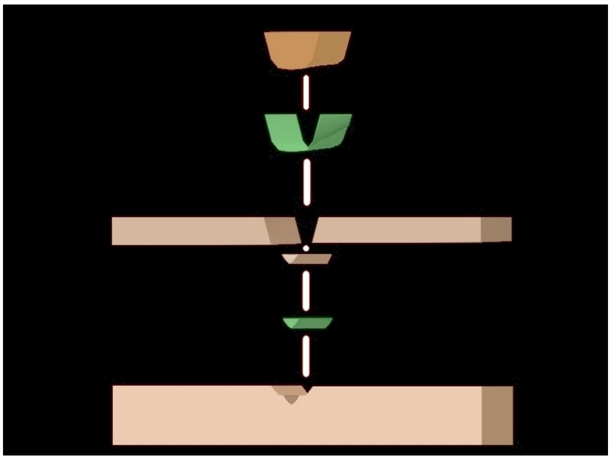

Figure 6: *"Vertically-exploded" model. Surfaces of cuts in green. Upper deposit and fill of earlier ditch have been grouped together in the same phase.*

4. The benefits of a 3D excavation model

The implications of modeling excavations in 3D are profound and extensive. Using a 3D model as a basis of an excavation record in the way described in this paper will have many benefits.

A new generation of digital acquisition tools will mean the data gathering will be simpler and much faster than manual drawing. This will result in great increases in productivity and reduction of the costs of commercial excavation.

The data that is recorded with these tools will be more accurate and contain more information than drawings, yielding a record of considerably better quality. In so doing, we will improve the "Preservation by Record" of our cultural heritage.

Working with a single 3D model will be a vast improvement over working with folders of drawings when it comes to visualisation of an excavated site.

Software tools which allow us to manipulate the appearance of a 3D excavation model will be powerful analytical aids for creating matrices, phasing the site and for volume analyses.

Links between contexts and their relevant database files will allow us to integrate all the excavation data on computer. The 3D model then becomes an interrogative front end to all the excavation data. Access to data becomes simpler and faster, publication and dissemination of results becomes easier, and it becomes possible to further integrate these results within landscape and regional models.

5. New Possibilities

Additionally, we might explore new opportunities that we have not yet considered in our modeling of the excavation.

5.1. Probability Surfaces

Current recording practices leave very little scope for uncertainty and practically force the excavator to commit to the belief that a boundary is real. In a 3D model we might employ probability surfaces to represent uncertain or hypothetical interfaces to more accurately represent our ideas at the time of excavation and subsequent interpretation. Such boundaries could be linked to photographs and even video or voice files in the databases in which the excavator describes the uncertainty.

Another type of probability surface we might employ could be the "sealing over" of postholes and other cuts (or negative features) to give a more realistic representation when we are visualizing phases prior to these interventions.

5.2. Different excavation methods

3D models of excavations could also let us explore different methods of excavation from the usual single context method, perhaps in response to the recording of difficult sites. For example we might excavate by "retreating section" in terrain with poorly visible stratigraphy. By linking the boundaries barely visible in successive sections we could create a 3D model which might be used to virtually "re-excavate" the site in single context fashion.

Summary

I envisage a future excavation record in which 3D graphical data for all deposits, interventions, finds and other archaeological features are displayed in relation to each other as a 3D computerized replica of the excavation, and where the graphical representation of each of these entities is linked to the relevant text, photographic and other data held in the site databases, effectively integrating the entire excavation record.

Such integration will result in new ways of managing, archiving and interrogating data by different user groups (excavator, cultural resource managers, museums, public).

Recording will be quicker and more accurate with software tools to improve visualisation and analyses.

3D models of excavations will have enormous advantages over current methods to the degree that I believe they will represent the most significant advances in the recording of archaeological excavations in the 350 years since such records began with Chifflet's publication of the excavation of Childeric's tomb in Tournai, Belgium (CHIFFLETIO, 1655).

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