

From Excavation drawing to archaeological playground: CAD applications for excavations

Willem Beex

(*Institute for Pre- and Protohistory, University of Amsterdam, Amsterdam, The Netherlands*)

15.1. Introduction

Nowadays field drawings are the basis of every excavation. In interpreting archaeological remains, one might even consider them to be more important than the actual artefacts. Therefore it is strange in a way that the use of a computer as a drawing processing tool is still very modest. Bearing this in mind, the institute for Pre- and Protohistory of the University of Amsterdam (I.P.P.) started working with a CAD system almost four years ago. It is now considered to be a highly efficient computer application, although its use has been limited to only a few types of excavation since both hardware and software will not allow a full reproduction of hand-made coloured plans at this time. Only the outlines of features can be digitised. But digitising drawings just for the sake of it does not have any archaeological value. The purpose must be a necessity to process this kind of graphical information. The main targets the I.P.P. defined are a swift general view, linkage with attribute databases and reconstructing the recorded visual remains of trenches. Three type sites will be presented, each showing one of these aims. In combination they reflect the full range of successfully tested possibilities¹.

This paper is a combination of the author's presentation in Aarhus, CAA92 and the computer demonstration in Stoke-on-Trent, CAA93. Due to obligations for an extensive campaign at the excavation in Wijnaldum immediately after the 1992 Aarhus conference, there was literally no time for writing within the period before the CAA92 papers deadline. Therefore one additional example, not presented at Stoke-on-Trent will be given.

15.2. Combining multiple co-ordinate systems at Geldrop

In 1989 plans were made to extend the municipality of Geldrop, province of Noord-Brabant². An area of over six hectares was threatened by this construction work. In order to avoid conflicts with the developers the I.P.P. used the planned layout of the roads as a basis for positioning the trenches. In fact this strategy benefited both the municipality of Geldrop and the archaeologists as double or unnecessary soil removal was limited. The only disadvantage was the actual layout itself. Probably designed by Post-modern architects a non rectangular road plan was used³. With only basic equipment present for this emergency excavation, over twenty temporary co-ordinate systems had to be defined. The local authorities provided the I.P.P. with a list of national grid co-ordinates of all main measurement points.

Simple mathematical procedures made it possible to combine all graphical information, but in reality each transformation took a long time. For a small excavation, this would have been no severe problem. The site at Geldrop already produced over forty 1:50 scale drawings in the first campaign, that had to be inserted into a general view. With the CAD system just operative, the idea digitising the field drawings was suggested. In this particular situation the use of this system at low level was extremely satisfactory. Each drawing could be digitised according to its own local co-ordinate system and scale. In fact it was possible to define all co-ordinate systems in the same drawing file. And standard options were present to change to one of the grids even adjusting the viewpoint (Figs. 15.1a & 15.1b).

The archaeological information of the site was almost ideal. Up to 1992 about thirty clearly defined structures were found. The number of finds for each individual feature was limited, although sufficient for interpretation. As a result, the use of a computer as an attribute database⁴ would mean overkill, while the creation of a spatial database saved a considerable amount of time. This example from the excavation at Geldrop can therefore be used in a discussion on when to digitise drawings if no additional computerised data are present⁵.

Transferring a drawing into a computer (without any links) will take about 20% more time than an experienced draftsman needs to make a 1:1 scale reproduction on a transparency⁶. But once part of a graphical database a number of advantages appear. It is possible to produce an unlimited amount of hard copies at any desired scale. Dealing with multiple co-ordinate systems is no problem at all, as long as at least two reference points are available. Different scales of the originals do not matter either, since the input will follow any chosen basic unit. The actual digitising however will not tolerate a range greater than a factor of ten, due to the limitations of accuracy obtainable with a pointing device, leading to some error. This error is estimated at 0.5mm. for any normal pointing device. A unit in the graphical database may stand for inches, centimetres, yards, miles or kilometres. If a mistake in measuring features of a particular trench occurred, this will clearly be shown in the general view. If this mistake was a constant one, corrections are quite easy, both in the original drawing and in the computer storage. For any reasonable decision these advantages have to be weighted against input time, program training time, output possibilities and the complexity of the overall view, also bearing in mind the loss of colour in the reproduction of the graphical information.

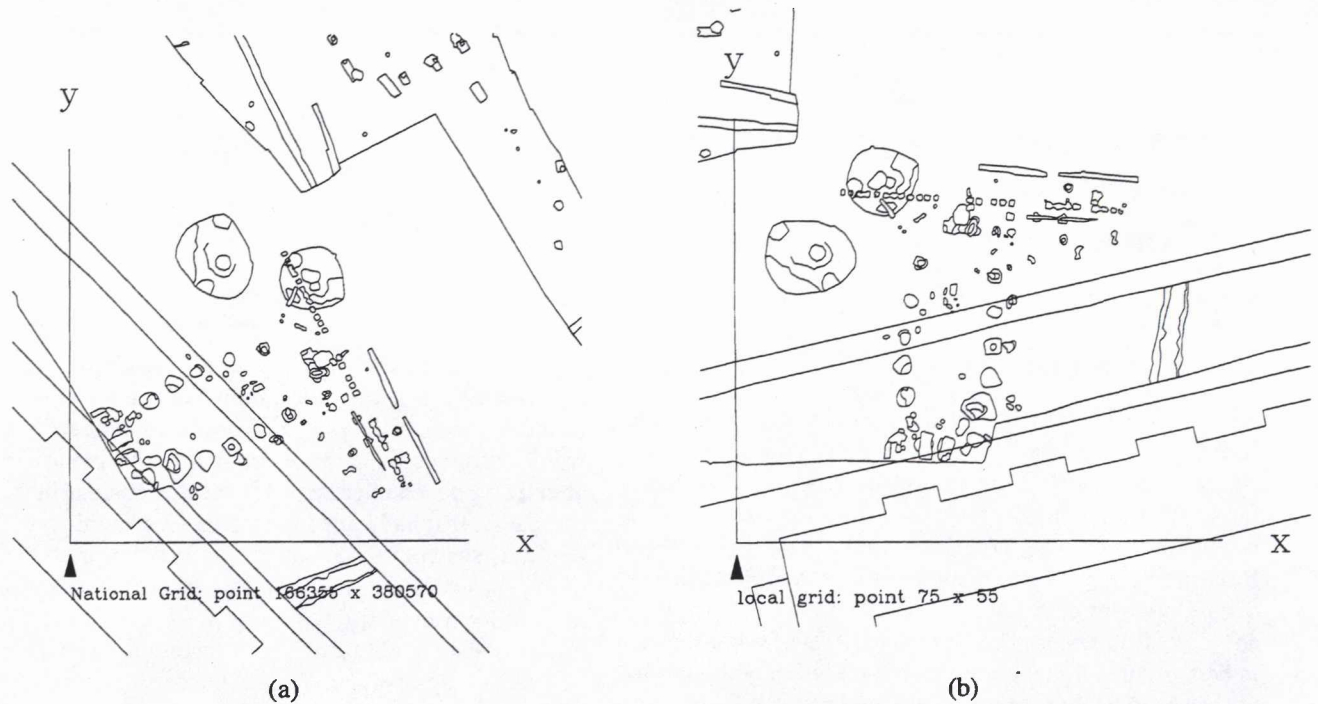


Figure 15.1: Part of the excavation at Geldrop with the remains of a twelfth century farmhouse; (a) shows this structure positioned according to the national grid, and (b) shows this structure positioned according to the local coordinate system.

Unfortunately no fixed turning point can be provided. The author can only make a comment, based on his own personal experience. If an excavation has to deal with twenty handmade drawings, each containing information on important archaeological structures, representing random parts of an area of at least one hectare, the use of a CAD system will almost certainly be valid. (The assumption has been made that equipment and personal are already present. But in real life many other factors can play an important role.)

15.3. Linking the graphical database with the attribute database at Gennepe.

Between 1988 and 1990 a Late-Roman/Early Medieval site was excavated at the confluence of the Meuse and the Niers⁷ at Gennepe, province of Limburg. Over 8000 features were recorded, and a multitude of finds. The investigated area was 100 wide by 350 metres long. More than 300 drawings of A0-size were produced in the three years of campaign. Interpreting all this amount of information can no longer be done by one person. The scientific staff will have to rely on the reports of students and assistants on individual find groups. And those reports have to be inserted into a general view of the site for further interpretation⁸.

Using a computer to store all available data was nothing more than a logical approach to this abundance of archaeological information. But one serious question emerged. Extracting data out of a CAD drawing can be done in two ways. Using "blocks" with "attributes" is the standard option. But blocks have a fixed insertion point. Therefore this method is only suited for adding attribute information of height measurements or point locations of

finds onto the computer drawings. If finds are collected for each feature, they do not possess a fixed co-ordinate. Spatial information is then gathered from the combination of a trench- and feature number reflecting to certain polylines in the digital drawing. In order to visualise an attribute database selection all related polylines have to be highlighted or changed into another colour. For the CAD system the I.P.P. used, this proved to be no real problem. It focused however on the need of modelling existing software to archaeological demands⁹.

A linkage with features and attributes also demands a special way of digitising. Focusing on the features, there are several occasions in which one polyline forms the boundary between two of them. This will occur if one feature cuts through another. This part of an outline has to be inserted twice as a part of a key in an attribute database, accompanied by other identifying elements, in Gennepe the trench and feature number (Fig. 15.2)¹⁰.

One final graphical problem occurs in making distribution maps. If for an archaeologically important artefact group both the quantity and the related features are known, there has to be a way to insert understandable symbols at the right spot. But the standard linkage with the polylines in a computer drawing will not immediately provide a suitable insertion point. Therefore again the moulding option of the CAD program had to be used. A "centre point" of each feature was automatically produced, based on all registered human point (vector)-input. This computed centre point is presented in a series of movable blocks, making it possible for an archaeologist to adjust this mathematical pinpointing according to present aesthetics. Once customised, these blocks can automatically provide an interface between the graphical and attribute database.

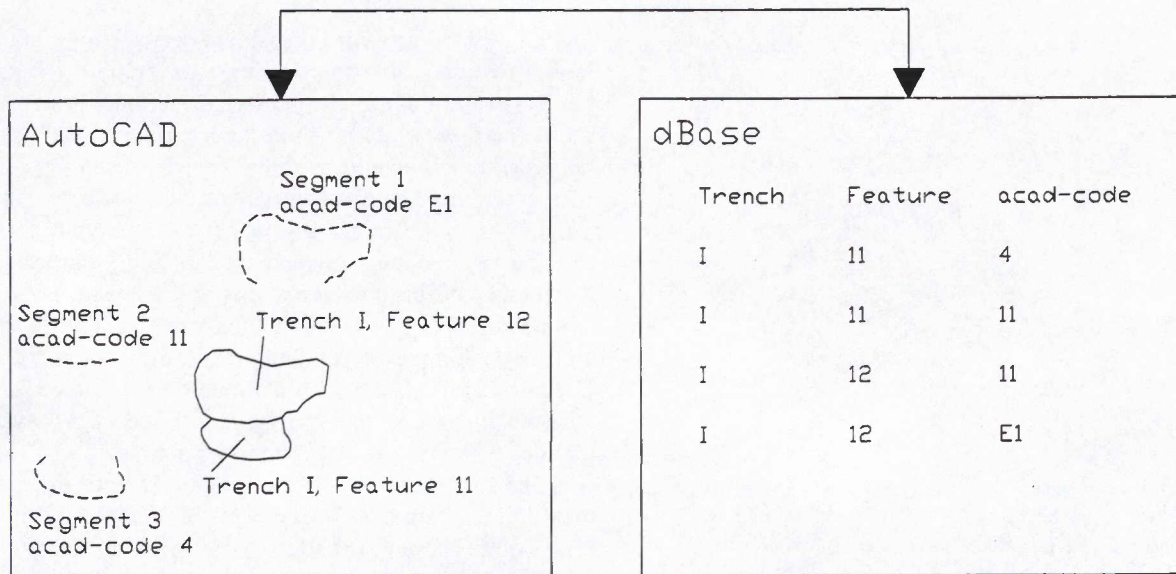


Figure 15.2: The principle of combining the outlines of features with an identifying attribute key.

This use of CAD/database combination is quite similar to a vector-based GIS (Geographical Information System). Yet there is one major difference, which is of the utmost importance in dealing with excavation drawings. A CAD-program has no need for bounded areas as any vector-GIS known to the author does¹¹. In registering archaeological features it is often impossible to make an absolute distinction between two types of soil. The situation will for instance occur if the last remains of an ancient ditch are encountered (Fig. 15.3). There may be an extensive "twilight zone" from an observational point of view. If an archaeologist were forced to present fixed boundaries due to software demands, this could cause premature interpretations and unnecessary faults¹². The fact that a CAD-file actually can be considered as translation of any random line-drawing into a database, makes it extremely suitable for this kind of application in excavations.

Introducing this application for excavation use requires additional programming. The CAD-system of the I.P.P. already possesses a SQL-based interface. But the previous described situations, with one line, referring to two features and the possibility to produce centre points, are typical archaeological problems, not implemented in any present P.C.-based CAD¹³. If such an elaborate use of a program is intended (as will be the case for any GIS), both knowledge and education should be present¹⁴.

Digitising an excavation plan for this purpose should be considered if a variety of attribute data is (or will be) present in the computer. A decision can be made whether to transfer all original graphical information, or to use a schematic background image. The latter option will obviously extremely reduce the input. A transfer of an excavation drawing, including linkage with attribute databases will take two to three times the amount of time to make a hard copy by hand.

15.4. Adding the third dimension at Wijnaldum.

In the Dutch coastal environment, dwelling-mounds (terps) are a normal archaeological phenomenon. These artificial hills were raised in order to protect the ancient population from flooding by the open sea. Terps were mainly occupied until the construction of the dikes, starting in the twelfth century. Therefore the monuments often have a thick deposit of human origin with a complex stratigraphy. Archaeologists who work in medieval towns or tells in south-west Asia, will recognise this problem of being confronted with an unpredictable mixture of agricultural, funeral and settlement activities for each remaining level.

In 1991 excavations started at Wijnaldum, province of Friesland¹⁵, followed by a second campaign in 1992. They revealed part of a dwelling-mound, occupied from Roman times till approximately the twelfth century. The site was chosen as a case study. Dwelling-mounds were among the first archaeological monuments to be protected by law in the Netherlands. As a result almost no modern investigations were at hand. In Friesland however they are the main source for an important period in time. During the sixth and seventh century "Kings" or "Dukes" are mentioned, indicating an important role of the area, related to both the emerging Frankian Empire and the conglomerate of Anglo-Saxon tribes. (In Beowulf, Finn, "King of the Frisians" is presented, although his tale will not encourage local nationalism.)

In the meantime questions emerged regarding the state of preservation of these monuments. With fierce winds and rainfall (storms up to Force 9-10 Beaufort each year) and limited, but still present agricultural activity, erosion seemed to be evident.

It became quite obvious new investigations had to be carried out. A find of a gold fibula decorated with almandine stones in the 1950s, closely related to the grave-goods of the Sutton Hoo main burial, simplified the decision to choose this particular terp by the scientific staff. As full-scale ex-

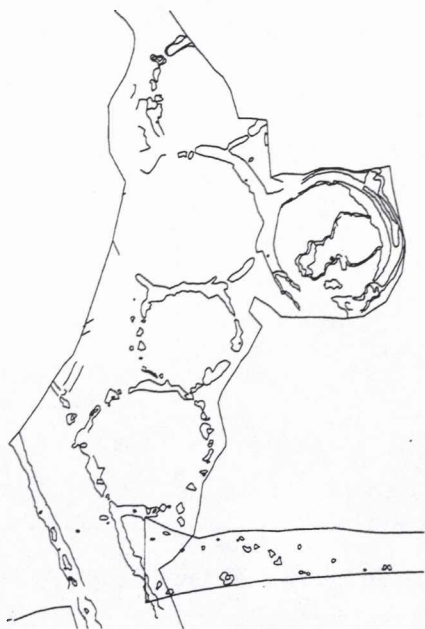


Figure 15.3: Urnfield ditch with many "open ends."

cavations took place on an official monument for the first time, this choice is, of course, still a subject of debate in Dutch archaeology.

In the two years of this project over 25,000 artefact groups have been registered. The find spots were indicated on drawings as point locations. An extensive number of height-measurements were taken because of the importance of the third dimension. The use of a computer is not surprising in this situation. Quite extraordinary however was a synchronised processing of finds and graphical information. This enabled all recording activities to be very accurate and up to date. In fact there was a three way check for each element in the attribute database. Hand-written records were inserted into the computer. After this stage the computer would provide a list, used to check the actual contents of a box with finds. All irregularities were cross-examined with the hand-written records. Finally remaining mistakes were adjusted in the computer and a new list was provided. This sequence would be repeated until no more errors were found. It may seem rather elaborate to outsiders, but this recording of basic administrative information in the field with artefacts, drawings, participants, and even the actual trench present, is far more accurate, much faster and easier than postponing these activities till after the actual excavation. Also parallel digitising of drawings improved accuracy as miscalculations in co-ordinates became apparent before any damage was done. A disadvantage may be the necessity for more personal present at the site.

More important for archaeology itself is the ability to produce instant (general) distribution maps (Fig. 15.4). With the right logistics even a basic interpretation of a trench is at hand, before a new level is made. It means that synchronised computer registration of graphical and attribute information can improve the actual field-work.

However only two-dimensional digital copies of drawings were used. In the complex stratigraphical situation the use of these flat maps is limited. A three-dimensional representation would be more appropriate. Dealing with only one trench-level or with the environment of a site, the I.P.P. often uses the commercial software-package SURFER. This program will make a grid out of three values where the first two columns stand for the x- and y-co-ordinates. A handicap of this package is that only one mesh of a grid can be shown at the time. The advantages are the speed and the techniques of this application in creating a grid. Considering that the representation of a grid-file in SURFER very much looked like a "polygonmesh" in a CAD-system, the idea arose of combining the two programs.

The first stage was to use the blocks with the height-measurements from an individual CAD-drawing. With this it was quite simple to produce a data-file for SURFER. The second stage was the processing of this information by SURFER and resulted in a grid-file in ASCII-format. The only thing left to do was to write a special application that could read this file and interpret it. Finally an automatic command would create the polygonmesh as part of a three-dimensional CAD-drawing (Fig. 15.5).

In using different commercial software as modules for an overall task, as was already done in using an attribute database, the advantages of each individual package can be fully used. The speed in processing height-measurements of SURFER was linked with the professional drawing-capabilities of CAD. Therefore more than one mesh could be graphically presented, being regarded as normal entities of an image. In Wijnaldum it meant that the surfaces of trenches could be organised in layers¹⁶ and colours. With standard options as "hidden lines" and "shading" the position of levels from adjacent trenches could be examined. This made it possible to determine differences in height for connecting field-drawings. Therefore if certain supposedly continuous structures were not observed in an adjacent trench, this visual representation of the surface could indicate to what extent recording might have been disturbed physically. In any other case the problem could be referred to the responsible archaeologist.

As information of the surface of a trench-level can only be obtained after it has been established, there is obviously no physical correction possible. It can however improve the interpretation of the site. And moreover it will clearly focus on human errors, both in recording and the progress of digging. As a result the excavation-staff (1991/1992) of Wijnaldum, including the author, considered this computer-application also to be an objective 'corrective device.' Therefore even on official visits by colleagues, politicians and possible sponsors mistakes, this CAD-visualisation made clear, were shown, as they could be traced down and evaluated before further actions were taken.

Cross-sections in stratigraphic excavations are extremely important. Manually creating a general view of the longitudinal and latitudinal information of a site is almost impossible. Yet a simple feedback with the basic use of co-ordinate systems, as already presented in the Geldrop example, enables archaeologists to position each drawing of a cross-section in its actual place. Only one condition is

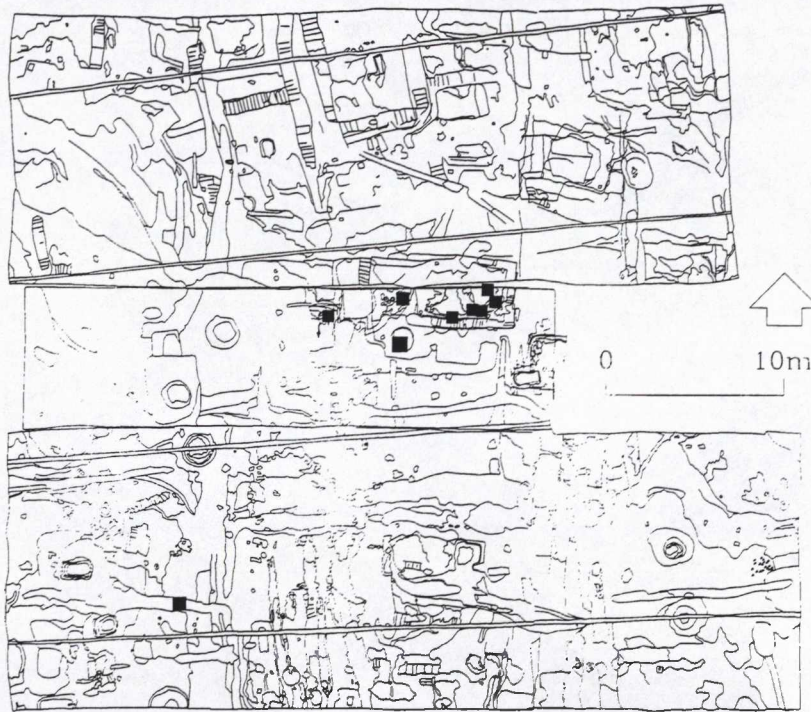


Figure 15.4: Distribution map of equipment for producing textile in a part of the excavation at Wijnaldum, province of Friesland. The artefacts cluster inside the remains of a small building of the seventh century AD.

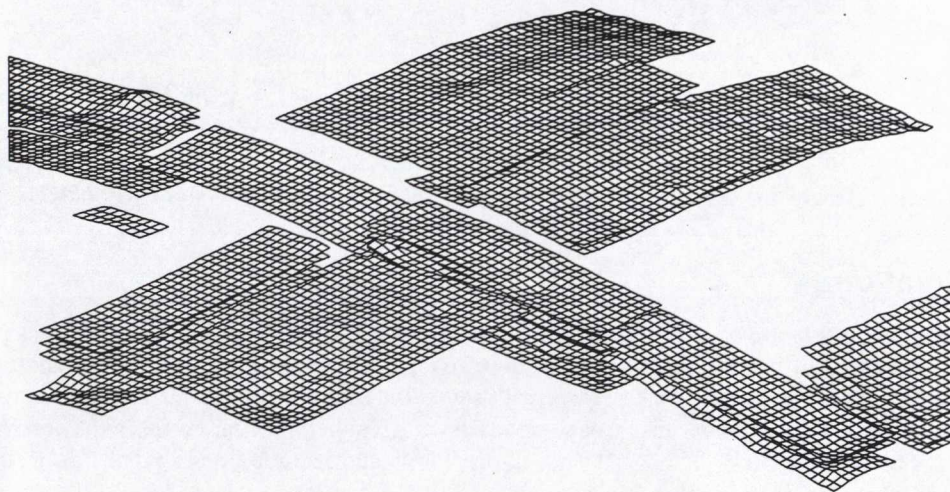


Figure 15.5: The relation of the different levels between trenches has been made visible in using "polygon meshes" for the excavation of the dwelling-mound (terp) at Wijnaldum.

necessary. Reference-points need to have a three-dimensional co-ordinate. Since cross-sections in the Netherlands are drawn according to a fixed height-level, only the position of a start- and endpoint relative to the horizontal plan have to be known. Afterwards digitising and viewing can be done in exactly the same way as for any drawing of a trench-level. All images can be combined in one CAD-file, allowing the archaeologist to walk through his excavation and observe the vertical information (Figs. 15.6a & 15.6b). At Wijnaldum the height could be exaggerated to improve visual appearance.

The next logical step was to combine all graphical information collected into a virtual reconstruction of the trenches. Of course this was easier said than done. It meant that two-dimensional drawings could be transposed on to the three-dimensional surface, an idea that needs considerable programming. The first complete automatic program was not operational till the autumn of 1991. It took about

45 minutes to transpose a 30 by 8 metres trench-level if the original drawing had a high density of lines. Better understanding of time-consuming operations within the CAD/LISP environment resulted in a second version early 1992, only altering one method of calculating the intersection-points. By now the same trench-level is remodelled in less than two minutes.

Having a three-dimensional representation of the levels and the cross-sections drawn on their original place, it was quite easy to combine these elements into one image. To improve visibility the trench-surface was shown without grid-lines and the cross-sections were placed against a plate. In using hidden lines and CAD-layers any viewpoint of a trench at a certain level could be provided. Additionally queries from the attribute-database could be inserted (Fig. 15.7).

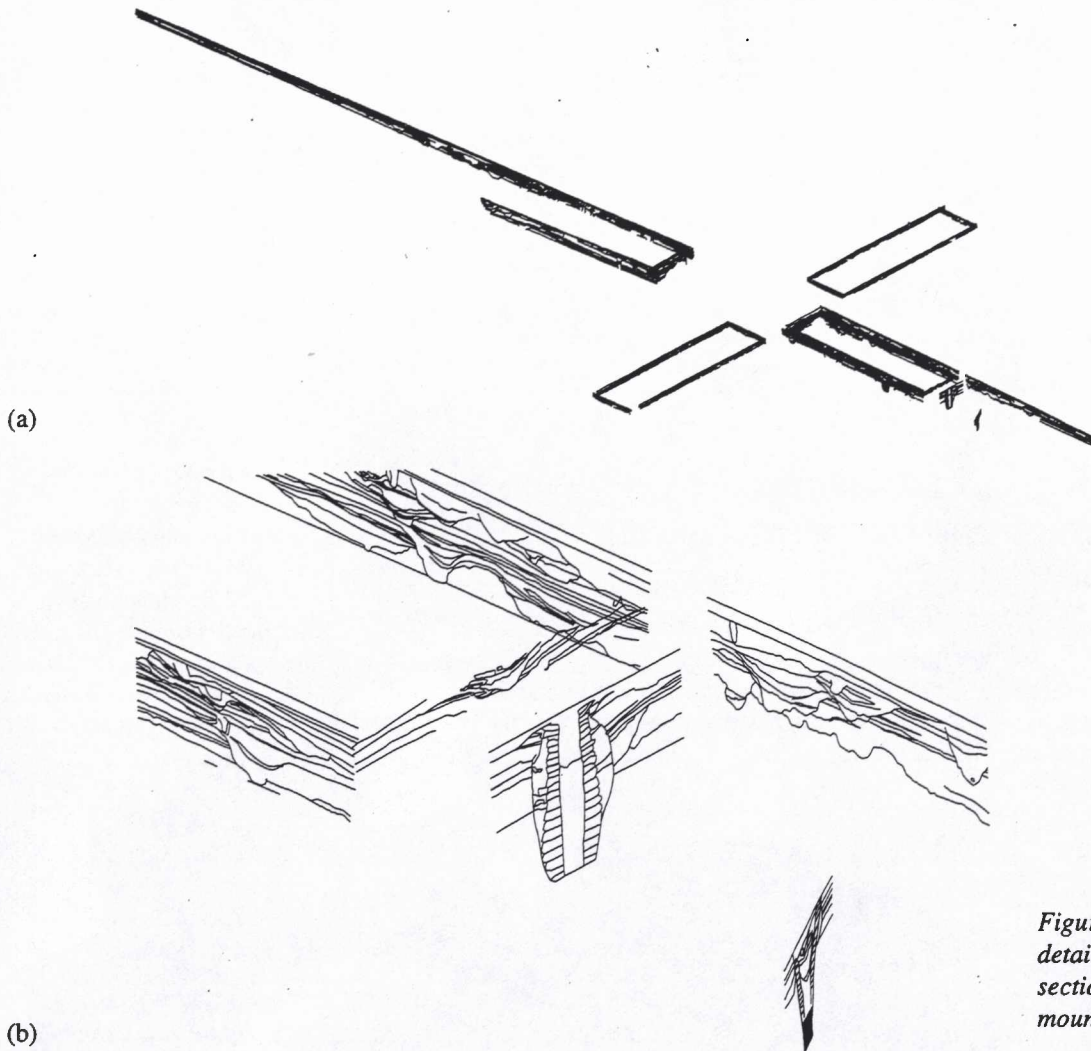


Figure 15.6: View (a) and detail (b) of all cross-sections of the dwelling-mound at Wijnaldum.

15.5. Further considerations

Dealing with a great number of drawings to be digitised, including information on find-locations and height-measurements should require an adequate computer log. During the Wijnaldum project the I.P.P. was able to solve this logistical problem using commercial software¹⁷.

The three-dimensional reconstruction of observations at an archaeological site can be seen as a first real enhancement made possible by the computer, after statistics were introduced. The importance of an attribute database may not of course be underestimated, but as in plane recording of drawings, it will only result in a easily accessible duplication of information¹⁸. It is in this field of further processing of the standard collected data, beyond normal human possibilities (at least without a full-time team of sculptors) that the focus should be.

The next stage will be undertaken with the Gennep project. Available archaeological and geological information on the original terrain will be used in a test to determine in which parts of the excavation present observations were disturbed. The same project also emphasised the need for information on function, density and volume of features in order to make worthwhile distribution-maps. The presence of a 3D-graphical database may therefore improve statistical approaches.

15.6. Conclusion

Modern CAD-systems are a successful tool in the digital recording of excavations. On a basic level the ability to work with several measurement-systems at the same time, can already be of great help. More useful is the combination with drawings and recorded descriptive information. Although this looks similar to vector-based GIS-applications, the CAD/database-linkage does not require areas to be bounded at all times. And in the archaeological recording of features loose ends are often encountered. The principle of CAD resulting in a digital drawing can be demonstrated in the possibility of reconstructing a trench in a full three-dimensional way. This ability to process standard field-drawings, based on standard reference-points and height-measurements proved to be an important enhancement for stratigraphical excavations. In combination with the attribute-database all recordings can be made visual, allowing better interpretation and eventual necessary adjustments for further campaigns.

Notes

1. The I.P.P. is currently using AutoCAD 12. AutoCAD 12 is available at low costs for educational institutes and includes full 3D drawing techniques. Even more important for archaeology is the open architecture of this software in combination with the LISP programming language.

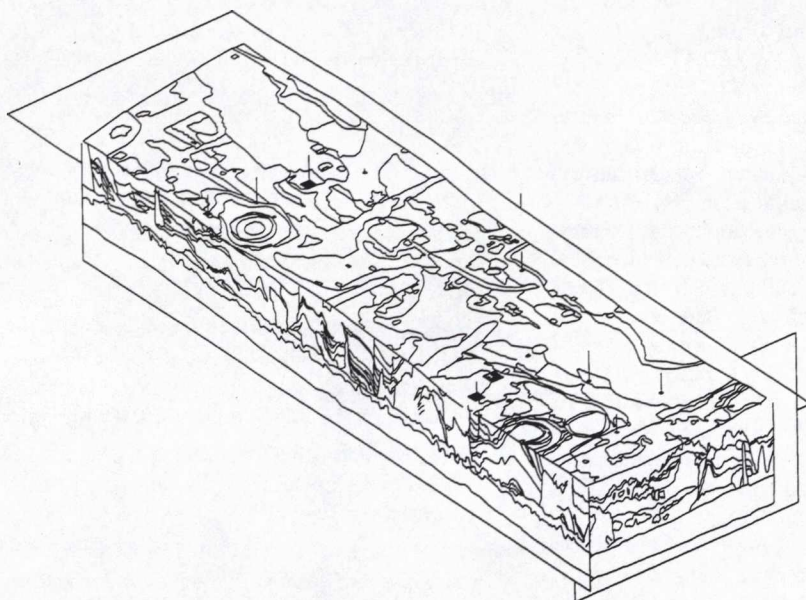


Figure 15.7: Three-dimensional representation of trench VIII at Wijnaldum. The "squares on needles" indicate the find spot and the number of third-century artefacts.

2. The excavations at this site are still in progress and are led by Dr F. Theuws, University of Amsterdam.
3. The junction of two roads seldom provides a right angle. In most cases this angle is between 25 degrees and 60 degrees. (In addition even the street names refer to the world of Tolkien. So people have addresses like 25 Hobbit Street.)
4. In this paper a distinction has been made between an attribute database and a spatial database. An attribute database contains descriptive information of a site, while a spatial database contains processable graphical information.
5. In this paper the assumption has been made that financial motives may not play an important role in the decision any more. Small excavations will hardly ever have the need for digital registration and any investment in medium- or large-scale projects should improve efficiency in such a way that it is profitable. The aspect of training and additional personnel involved is further considered in Note 14.
6. Throughout this paper input is considered to be done manually with a suitable digitiser. The use of scanners is limited for vector-based recording, as both hardware and software necessary are still very expensive.
7. The Niers used to be a river suitable for medium-sized river boats, almost connecting the Meuse with the Rhine. The source is near the German city Dusseldorf, within one hours walk from the Rhine. Geologists' reports indicate that the Niers actually was the Rhine during the last Ice Age.
8. The overall interpretation of this site is being conducted by Dr A. X. Koelman, University of Amsterdam.
9. Using the "Handles" option in AutoCAD proved to be the easiest way to link graphical and attribute information. Handles are fixed hexadecimal numbers, identifying any entity in the CAD drawing. Two AutoLISP applications were written, one to combine handles with fixed trench and find numbers in an ASCII file, ready for insertion into an attribute database, and the second to transform the handles of an attribute database selection into an AutoCAD selection set.
10. This procedure was already available at the I.P.P. within AutoCAD 10, long before the introduction of the AutoCAD 12 SQL extension. Quite important is the fact that the actual drawing is not extended with a huge amount of additional data, whenever these can be more easily stored and processed by a database manager. Only a handle is added to each entity, never extending the size of a drawing by 1%. While using the "Shroom" option in loading our basic software AutoCAD, there is enough room available for switching to other applications without actually leaving a drawing session. The only disadvantage is the temporary storage of information to be transferred in ASCII files.
11. The author is aware of the fact that the development in software is extensive. Within the CAA and the UISPP (Commission 4) networks nobody has ever mentioned a vector-based G.I.S. that could handle an incompletely bounded area. This may, however, not be so. If the reader has encountered such a program, the author would be grateful to be informed.
12. A computer application for excavations may never change any archaeological procedure for its own sake. It can, however, alter standard recording techniques when digital processing focuses on efficiency and common errors, as stated later in this paper.
13. Any AutoLISP program described in this paper is regarded as Public Domain to any archaeological institution. This means that all programs can be obtained if the cost of two diskettes and postage costs are sent to the author. They may also be copied by third parties without notice. In all cases the AutoLISP source code will be unencoded, as no commercial use is intended. By implication, no warranty can be given for problems which occur. Manuals, updates and trouble-shooting can be provided, however, with agreement of costs on an *ad hoc* basis (time and materials). This attitude towards archaeological modification of commercial software has been agreed by the Institute for Prehistory, University of Leiden and the I.P.P., University of Amsterdam. It has been introduced by Dr H. Kamermans, Dr M. Wansleben and the author. Since no trademark will be involved, we regard non-commercial applications as an archaeological paper. The programmers should be acknowledged at all times, particularly if their work is to be used for further applications. CAA and UISPP should guarantee this, if source codes are made available.
14. International co-operation should be considered, since it may not be possible for individual institutes to employ full time staff. A one-week training and development course has already been given by the author at the Free University of Berlin, and a four-month period of education is planned at the Institute for Archaeological Heritage of Flanders. In this last example education could be defined as a "product".

15. The project at Wijnaldum is a joint venture between the universities of Groningen and Amsterdam. Dr J. Bos (Groningen), and Dr J. Besteman and Prof. H. A. H. Heidinga (both from Amsterdam) form a "triumvirate" responsible for the scientific implications. The actual excavations have been carried out by a field-staff. As for the project of Gennep., also mentioned in this paper, independent reports will be made, finally resulting in general publication of the site.
16. A layer in a CAD system can be regarded as a transparency. These should not be confused with archaeological layers.
17. At the excavation of Wijnaldum the author received a "Goodwill version" of Automanager Workflow 2. This commercial package stores AutoCAD/DXF drawings according to a logical DOS fieldpath relation, determined by the user. All information on the status of the drawing can be added in a dBASE III/IV compatible database. Visual environment and use is directly based on Windows, although it can operate separately from this application. More information is available at Cyco Europe, Rijswijk, The Netherlands (Telephone: +31 70-3993054).
18. Attribute databases do have a corrective importance in archaeology. The necessity to store data in a fixed and logical way often implies reconsideration of the variables involved. These databases can therefore indicate which elements are descriptive for interpretations.

Bibliography

- ARNOLD, C. J., J. W. HUGGETT, P. REILLY, & S. SPRINGHAM 1989. "Mathrafal: a case study in the applications of computer graphics". In Rahtz, S. and J. Richards (eds), *Computer Applications and Quantitative Methods in Archaeology 1989*, BAR International Series 548, British Archaeological Reports, Oxford, 147-156
- AUTODESK 1992. *AutoCAD release 12 Reference Manual*, June 1992, AutoDESK, Neuchatel
- AUTODESK 1992. *AutoLISP Programmers reference*, June 1992, AutoDESK, Neuchatel
- BEEEX, W. F. M. 1990. "Site du Bas-Empire a Geldrop (Eindhoven, P.B.)", *Bulletin Trimestriel d'Information du Centre Interdisciplinaire de Recherches Aeriennes* 13ème Année, 1-6
- BEEEX, W. F. M. 1990. "Ontginningen in een feodale wereld", *Tussen Zesgehuchten, De Laat-Romeinse en middeleeuwse bewoning van Geldrop-'t Zand*, 38-52
- BEEEX, W. F. M. 1991. "Computerzeichnungen in der Archäologie, Nachlese Computer-Anwendung", *Archäologische Informationen* 14(1), Bonn
- BEEEX, W. F. M. 1993. "AutoCAD in the Field", *EC-Cadence* March 1993, 55-58
- BEEEX, W. F. M. 1993. "Excavational Information System", *CSA Newsletter of the center for the study of architecture*, in press
- BEEEX, W. F. M. 1993. "Graphical Fieldwork: A History of its Introduction", *Data management and Mathematical Methods in Archaeology*, in press
- DELOOZE, K. & J. WOOD, 1991. "Furness Abbey Survey Project". In Lockyear, K. and S. Rahtz (eds), *Computer Applications and Quantitative Methods in Archaeology 1990*, BAR International Series 565, Tempus Reparatum, Oxford, 141-148
- HEIDINGA, H. ANTHONIE OFFENBERG & GETRUDIS A. M. OFFENBERG 1992. *Op zoek naar de vijfde eeuw: de Franken tussen, Rijn en Maas*, Amsterdam.
- JONES, F. H. & L. MARTIN 1989. *The AutoCAD Database Book: accessing and Managing CAD Drawing Information*, Chapel Hill, North Carolina
- REILLY, P. 1991. "Towards a virtual Archaeology". In Lockyear, K. & S. Rahtz (eds), *Computer Applications and Quantitative Methods in Archaeology 1990*, BAR International Series 565, Tempus Reparatum, Oxford, 133-140
- VOORRIPS, A. & W. F. M. BEEEX 1993. "TIA: Toegepaste Informatica in de Archeologie". In Bloemers, J. H. F., W. Groenman-van Waateringe & H. A. Heidinga (eds), *Voeten in de Aarde: een kennismaking met de moderne Nederlandse Archeologie*, 137-157

Dr W. Beex
 Universiteit van Amsterdam
 Instituut voor Pre- en Proto-Historie
 Nieuwe Prinsengracht 130
 Netherlands-1018 V2 Amsterdam
 wb @ nl.uva.frw.ivip