

The value of pseudo 3D techniques for the interpretation of analogue archaeological research

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Abstract: The use of virtual 3D techniques as a research tool in the interpretation of analogue archaeological data has gained little attention. The current paper will explore whether the use of 3D techniques can help to understand data from old archaeological excavations. A method is presented which facilitates the translation of analogue data into a pseudo 3D environment. One trench from the famous excavations of the early medieval trading town of Dorestad serves as a case study. This trench was excavated in 1970 and has never been published in detail. The trench contains a particularly large amount of features and has a complex stratigraphy. This makes it hard to interpret the features in the trench by traditional methods using two dimensions. In this paper it is argued that the creation of a pseudo 3D space of old analogue excavation data offers archaeologists the possibility to experience and understand the data in a way which is not possible when the data is experienced in only two dimensions. Experiencing old archaeological data in three dimensions from different angles creates a spatial awareness of the features which helps to comprehend and interpret the features and structures in the trench.

Keywords: Pseudo 3D, digital archaeology, analogue data, Dorestad, GIS

Introduction

Virtual 3D techniques are increasingly being used in archaeology. Often these techniques are applied to create three dimensional models of ancient architecture in order to visualise old buildings for a large audience without much academic purpose. Since a few years virtual and real 3D techniques have come into use as a research tool in archaeological investigations. As a result of improvements and increasing affordability of hardware and software the range of applications in archaeology has widened. At present 3D applications in archaeology include techniques like laser scanning an ancient building or site (AKBOY 2010), the use of photogrammetry to create point clouds of objects or landscapes or virtually model a building literally stone by stone in order to understand the building's construction (LULOF et al. 2013). Most of the applications of virtual 3D techniques in current research deal with ongoing archaeological excavations and surveys or the virtual preservation of heritage. These techniques are valuable tools welcomed in a discipline which on the whole becomes increasingly digitalised. However, the use of virtual 3D techniques as a research tool in the interpretation of old or analogue archaeological data is largely uncharted terrain. The current paper will explore whether virtual 3D techniques can be used to help understand data from old excavations. The goal of this paper is to assess whether 3D techniques can contribute to the process of interpretation of old archaeological research. Preparing analogue data sets for 3D analysis is considered useful when with a reasonable investment in labour and money better information is generated

from the data set. An important factor in this process is how the construction of a pseudo 3D image of the excavation findings can be of use for the analysis of excavation data by researchers who analyse old excavation data from 40 years ago and were not present in the field at the time of excavation.

To determine whether pseudo 3D reconstruction of excavation findings and data contributes to the analysis of old excavation data we have used the analogue archaeological data of a trench from the well-known excavations of Dorestad. Dorestad was an early medieval trading town located in the central part of the Netherlands, near the present town Wijk bij Duurstede. This site was excavated from the late sixties onwards and has become one of the largest excavations in the Netherlands (VAN ES 1990; WILLEMSSEN and KIK 2010). The excavation archives consist of large numbers of field drawings, sketchy note books, black and white pictures and other analogue data. The excavations at Dorestad were performed under considerable time pressure and with limited means. Also for post excavational analysis insufficient resources were available. As a result the basic analysis of finds and findings of large sections of the excavation have not yet been carried out. Most work has been done on the excavations of sections of the harbour. These were published by the original excavators van Es and Verwers in 1980 and 2009 (VAN ES and VERWERS 1980; VAN ES and VERWERS 2009). Both authors are preparing a synthesizing volume on the central part of Dorestad. Within the framework of the Odyssee archaeological backlog programme of the Netherlands Organisation for Scientific Research (NWO) a project was initiated to analyse the cemeteries of Dorestad. As a part of this project the features and finds of the trenches in which burials were found have been analysed. Trench 136 which was a central trench in one of the cemeteries was analysed with pseudo 3D techniques. This trench was selected because it contained several findings which were difficult to interpret just by looking at the 2D documentation.

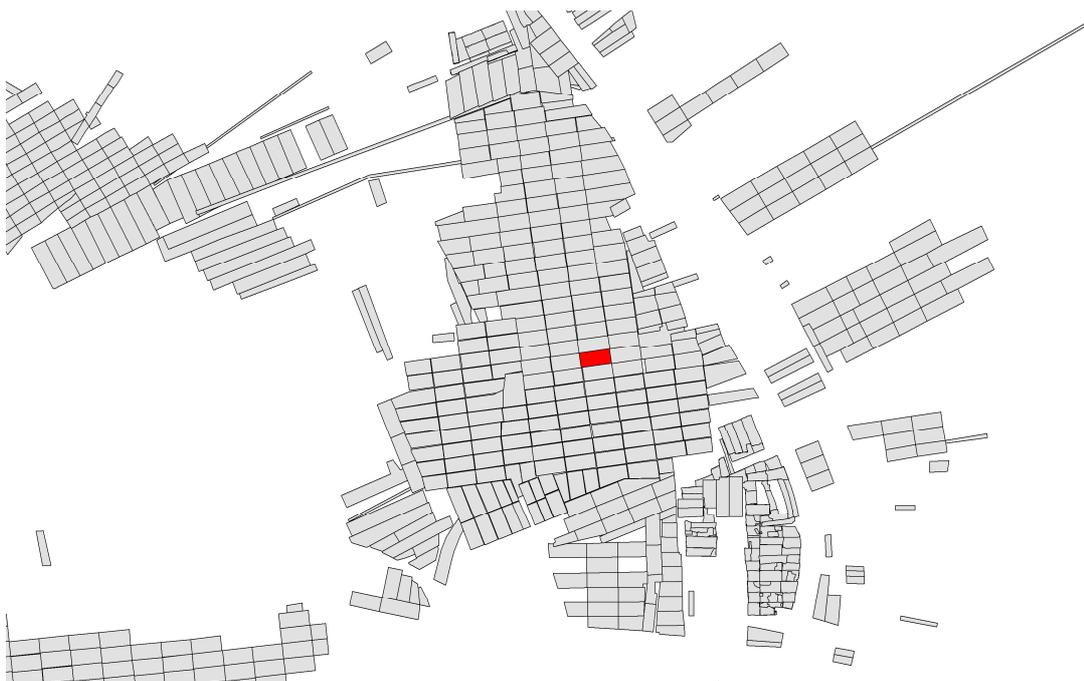


Fig. 1 – Overview of all trenches of the Dorestad excavations with trench 136 marked red. The digitalisation of the trenches was done by Benno Ridderhof from VU University in Amsterdam.

General overview of the method

The archaeological procedure used at the Dorestad excavations was designed for the huge surfaces to be excavated under time pressure. The available excavation data are the result of large scale excavations of trenches measuring 20 by 40 metres. These trenches were excavated in spits using a dragline with a bucket system. Generally a trench was excavated in three to six spits. Each level was then drawn on a scale of 1 to 50 on sheets of graph paper. These drawings on graph paper form the starting point for our method. In order to transform a couple of analogue paper drawings into a virtual pseudo 3D model, three basic steps were taken. First, the analogue paper drawings were digitalised and georeferenced using CAD software. This was done for the whole of the Dorestad excavations by Benno Ridderhof at the VU University in Amsterdam. The second step concerned the transformation of the digitalised CAD drawings into a GIS spatial database, in which all features were described in an attribute table (figure 2). This was the most time consuming part of the process and was done using ArcGIS 10.0. The last step was the creation of a pseudo 3D model based on the spatial database. The pseudo 3D environment was created with ArcScene using the settings Base Heights and Extrusion.

Pseudo 3D, also known as '2,5D', is the addition of a height value to every x and y coordinate. In other words, the two dimensional shape gets extruded and gains a certain depth. The three dimensional shape that is created cannot be changed other than what is possible in the original two dimensional shape. For example, a round post hole ending in a point cannot be made explicit in pseudo 3D and is thus represented by a tubular form.

Pseudo 3D can as a consequence not be used to create accurate representations of features in three dimensions. Instead, it may be used to give an insight into the relative position and depth of features. By using pseudo 3D, a level of abstraction is added to the source material which facilitates a systematic representation of findings, creating new opportunities to interpret the source material.

The case study: trench 136 and its problems

For our case study a trench was selected from the central part of the Dorestad excavations. Trench 136 was a trench in the middle of the De Heul site (see figure 1). This trench was excavated during the summer of 1970, measures about 20 by 40 meters and lies in the centre of an early medieval cemetery. The trench was excavated, using a dragline, in six different artificial levels, about five to ten centimetres apart. Next to 170 burial contexts, the trench contains many other archaeological features like post holes and wall ditches. Notable are the traces of structures among which a rectangular building in the central part of the trench. The rectangular structure measured about 18 by 8 meters and was made of wood, as the post holes and wall ditches suggest (see figure 4).

In comparison to other nearby trenches, trench 136 is relatively complex: it has a large amount of individual features (about 1000), many intercutting features and a complicated stratigraphy. This makes it hard to create an overview of the trench just by looking at the different drawings. As argued this makes the trench an interesting case to test the presented method.

context id tag	context type	context shape	recent	trench id tag	level max	level min	context z max	context z min	context z depth	cr
13601165	Pit	Other	No	136	1	1	428	428	5	<Null
13601166	Irregular disturbance	Other	Yes	136	1	1	428	428	5	<Null
13601170	Pit	Square	Yes	136	1	1	430	430	5	<Null
13601176	Irregular disturbance	Other	Yes	136	1	1	429	429	5	<Null
13601177	Unknown	Other	No	136	1	1	429	429	5	<Null
13601178	Unknown	Other	No	136	1	1	429	429	5	<Null
13601179	Unknown	Other	No	136	1	1	429	429	5	<Null
13601180	Unknown	Other	No	136	1	1	429	429	5	<Null
13601185	Unknown	Other	No	136	1	1	420	420	5	<Null
13601190	Unknown	Other	No	136	1	1	412	412	5	<Null
13601191	Excavation trench	Rectangular	No	136	1	1	417	417	5	<Null
13601192	Irregular disturbance	Other	No	136	1	1	417	417	5	<Null
13601196	Unknown	Other	No	136	1	1	423	423	5	<Null
13601197	Ditch	Other	No	136	1	1	422	422	5	<Null
13601198	Irregular disturbance	Other	Yes	136	1	1	422	422	5	<Null
13601199	Other	Other	No	136	1	1	422	422	5	<Null
13601200	Pit	Other	Yes	136	1	1	422	422	5	<Null
13601201	Other	Other	No	136	1	1	420	420	5	<Null
13601202	Pit	Other	Yes	136	1	1	420	420	5	<Null
13601204	Unknown	Other	No	136	1	1	420	420	5	<Null
13601205	Pit	Other	Yes	136	1	1	420	420	5	<Null
13601206	Pit	Oval	Yes	136	1	1	422	422	5	<Null
13601209	Irregular disturbance	Rectangular	Yes	136	1	1	422	422	5	<Null
13601210	Ditch	Other	No	136	1	1	420	420	5	<Null
13601212	Pit	Unknown	No	136	1	1	420	420	5	<Null
13602007	Pit	Rectangular	No	136	2	2	420	420	5	<Null
13602008	Pit	Rectangular	No	136	2	2	420	420	5	<Null
13602010	Posthole	Round	No	136	2	5	417	406	11	<Null
13602027	Pit	Oval	Yes	136	2	2	420	420	5	<Null
13602029	Pit	Other	Yes	136	2	3	415	415	5	<Null
13602030	Pit	Other	Yes	136	2	2	415	415	5	<Null
13602032	Posthole	Round	No	136	2	2	414	414	5	<Null
13602033	Pit	Rectangular	No	136	2	2	414	414	5	<Null
13602034	Posthole	Square	No	136	2	2	414	414	5	<Null
13602035	Pit	Rectangular	No	136	2	3	414	414	5	<Null
13602039	Posthole	Round	No	136	2	2	418	418	5	<Null
13602040	Posthole	Round	No	136	2	3	414	414	5	<Null
13602041	Posthole	Round	No	136	2	2	414	414	5	<Null
13602042	Posthole fill	Rectangular	No	136	2	2	414	414	5	<Null
13602045	Posthole	Round	No	136	2	2	416	416	5	<Null
13602047	Posthole	Round	No	136	2	2	416	416	5	<Null
13602049	Posthole	Round	No	136	2	2	418	418	5	<Null
13602050	Posthole	Round	No	136	2	3	418	418	5	<Null
13602051	Posthole	Round	No	136	2	3	418	418	5	<Null

Fig. 2 – The attribute table with information on context type, shape and elevation in ArcGIS.

Unfortunately the documentation of the features during field work was not without mistakes and inaccuracies. As the quality and precision of the source material ultimately determines the quality of the pseudo 3D model, it is important to understand the working methods, level of detail and precision of the field work and original documentation. The following inaccuracies in the documentation of trench 136 were found.

First of all, some elevation measurements were missing. When working in three dimensions, the height and depth of features becomes important. During field work, elevation measurements were taken on a regular grid covering the trench, but only of the first four levels. The two lowest levels lack information on the height and depth of features. Furthermore, some mistakes were made during the documentation of the elevation of the second and third level. When plotting these two levels, level three is situated above level two at some areas in the trench. This is of course not possible as level three was created after level two. This can only be explained with inaccuracies made during either field work or documentation.

A remark written on the drawing of level three says that during the drawing of the features, the surface was very dry so that some features were probably not visible and thus not documented.¹ This becomes evident when features drawn on both level two and level four are considered. They often are remarkably similar, suggesting that these are single features documented on multiple levels, but lacking on level three due to poor visibility of the features at the moment of documentation.

¹ The original note in Dutch: "Dit vlak is in uitgedroogde toestand getekend na fotografie. Waarschijnlijk grondsporen gemist".

Except for human remains, very few artefacts were recovered in the trench. In fact, only the first two levels have a couple of find numbers, the other four levels lack any find number. This is probably not due to a lack of objects but due to a different approach in collecting finds. Recent excavations in Wijk bij Duurstede do not show a similar absence of finds in the Dorestad layers (DIJKSTRA 2012). Because of the scarcity of finds collected from the various features it is difficult to determine the chronological order of features.

The last problem with the documentation of trench 136 is the small number of section drawings that were made (figure 3). Usually, section drawings give an insight in the character and size of features and thus are very useful when working with three dimensions. In this case, only five features were sectioned and drawn.

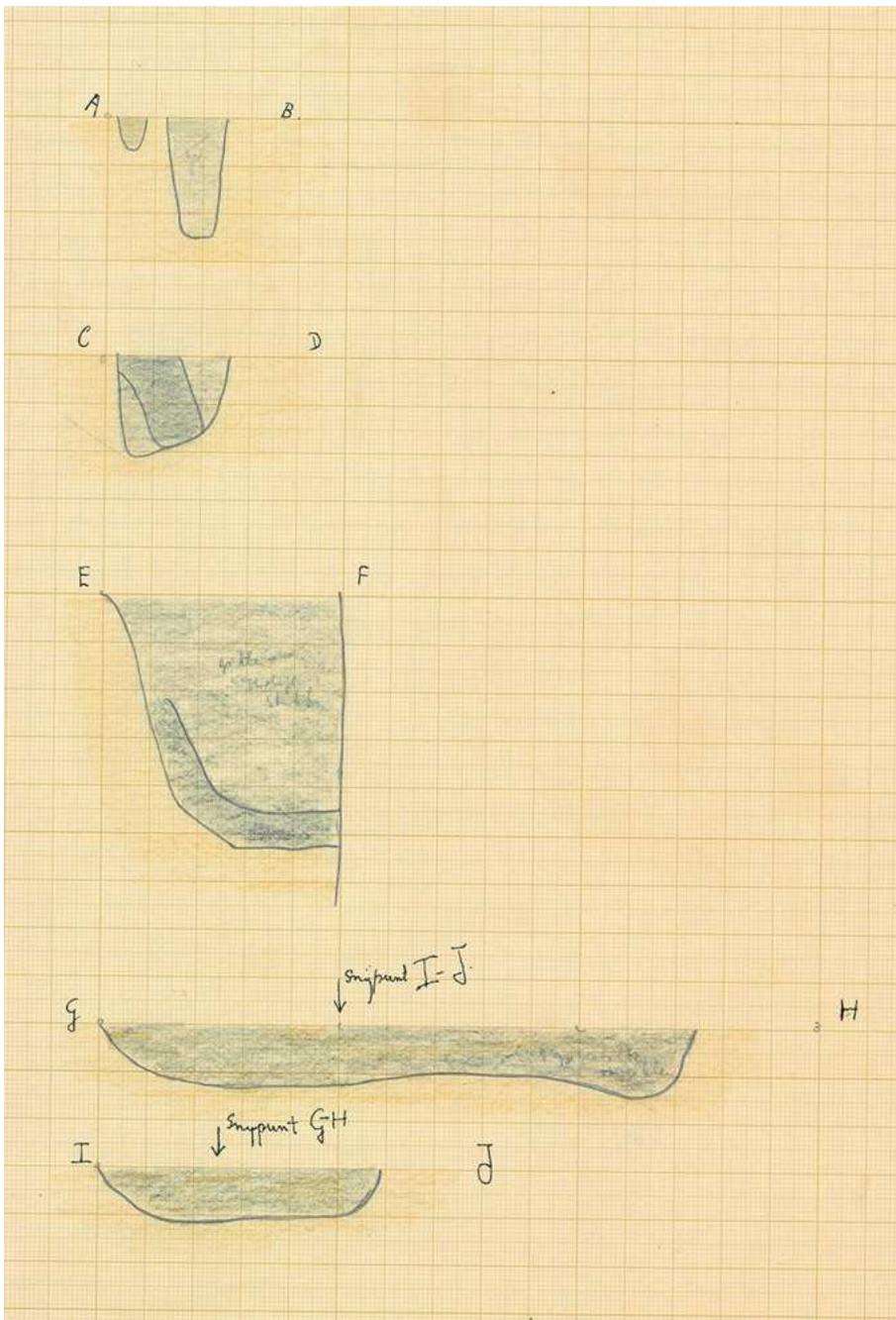


Fig. 3 – The five section drawings made for trench 136. The second section drawing shows a diagonally placed post hole. Original drawing by ROB, currently maintained in the RMO, digitally scanned by the authors.

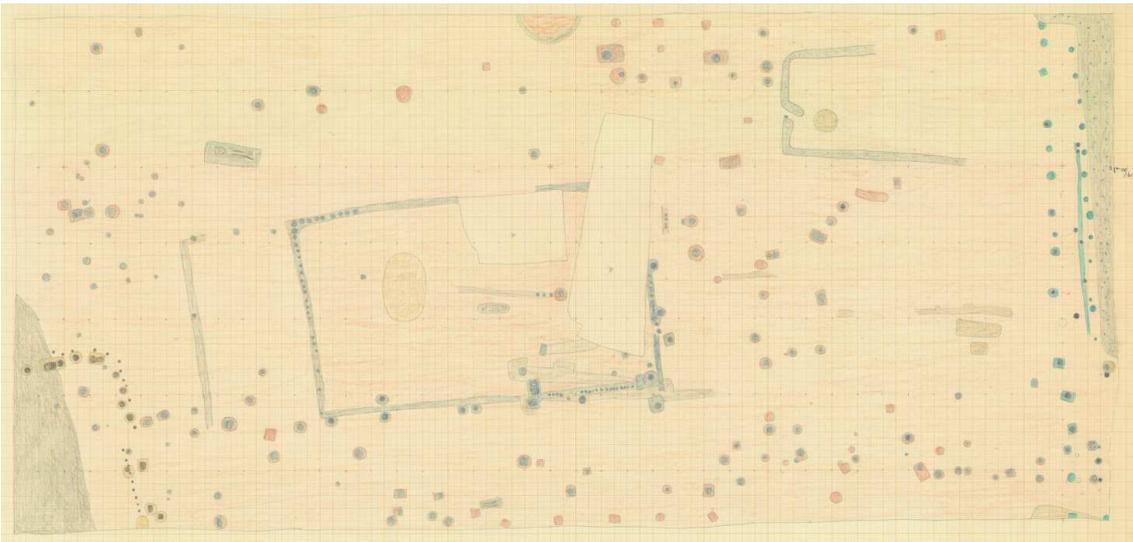


Fig. 4 – The original field drawing of level 5. The building in the central part is clearly evident. Original drawing by ROB, currently maintained in the RMO, digitally scanned by the authors.

Protocol

To systematically prepare the old excavation data for import into a pseudo 3D environment a protocol was created. The purpose of this protocol was to be able to work consistently and to be transparent about the choices made during the process of digitalisation and the creation of the spatial database. In the following, the practical steps taken from the import of the digitised field drawings to the pseudo 3D visualisation are summarised.

The first problems emerged when importing CAD files into GIS. Some polygons were duplicated while others were missing or incomplete. This might have to do with the fact that CAD and GIS deal differently with how geometries read are stored in files. This problem could easily be solved by calculating the exact x and y coordinate of every feature, then listing all coordinates and deleting the duplicates. The resulting polygons were then compared to georeferenced image files of the original field drawings. When missing or incomplete polygons were noted these were added by drawing them by hand in GIS.

All remaining polygons were given a unique number consisting of the following formula: ### (trench number) ## (level) ### (number), for example 13602025. By creating unique numbers, it will be possibly in the future to continue on different trenches without running into duplicate numbers. To save time, some series of features were digitally documented as one polygon. This was done in when features were clearly related and belonged to a single construction element, such as a series of small post holes.

At this point, the polygons in the GIS did not yet correspond with the individual features in the trench. That has to do with the fact that many features, especially those with a larger depth, were documented on different levels. At multiple instances there was one polygon for each level on which a feature was documented, meaning that many features were digitally drawn multiple times. The next step was to create one single polygon for each feature that was recorded in several levels. When two or more polygons were superimposed and had the same size, shape and fill in the original documentation, the polygons were

considered to be one feature. The upper polygon was normally used to represent the feature as a whole, while the other polygons were deleted.

Due to inaccuracies in the measurements taken during fieldwork, the polygons on different levels were often not exactly lined vertically. Relative deviations up to 25 centimetres emerged. This was visible in particular when groups of polygons showed the same deviations. When it could be argued on the contextual situation that multiple features documented on different levels with such deviations are in fact representations of one single feature, a composite polygon was created. The polygon containing the most information was chosen to represent the feature while the other polygons were deleted. Information concerning the elevation and depth of the feature was retained in the attribute table.

It is possible that the polygons with vertical deviations represent features which were placed diagonally in the soil, such as posts of early medieval house constructions. It is however very hard to make that conclusion when section drawings of the features are lacking. Often there was not enough proof to identify diagonal features. Based on the local context, inaccuracies during fieldwork served often as a better explanation for the vertical deviations.

Many features differed in size and shape on different levels. A post hole, for example, could very well end in a small round shape while on a higher level the shape is much larger and square. However, due to the lack of sufficient section drawings this could not often be proved with certainty. In some cases the size or shape of superimposed features could differ while there were good arguments to believe it to be the same feature. This may be explained by the drawing style of the different draughtsmen who worked on the different level drawings (figure 5). It became clear that some draughtsmen used a standardized version of a post hole, while other draughtsmen were more precise and drew the exact shape. This is particularly true for the drawing of level 3, which contains the above mentioned note on how some features were not drawn due to a dry and poorly visible surface. Many features on this level look very similar in both size and shape, as if the features were sketched instead of measured. In such cases, the polygon that was created to represent the feature was given the shape of the drawing with the most information.

As indicated the note on the level 3 drawing implies that some features were not documented at this level. When there were arguments to believe that features documented on level 2 and 4 were in fact the same feature, these features were brought together in composite features extending from level 2 to 4 even though these were not documented on level 3.

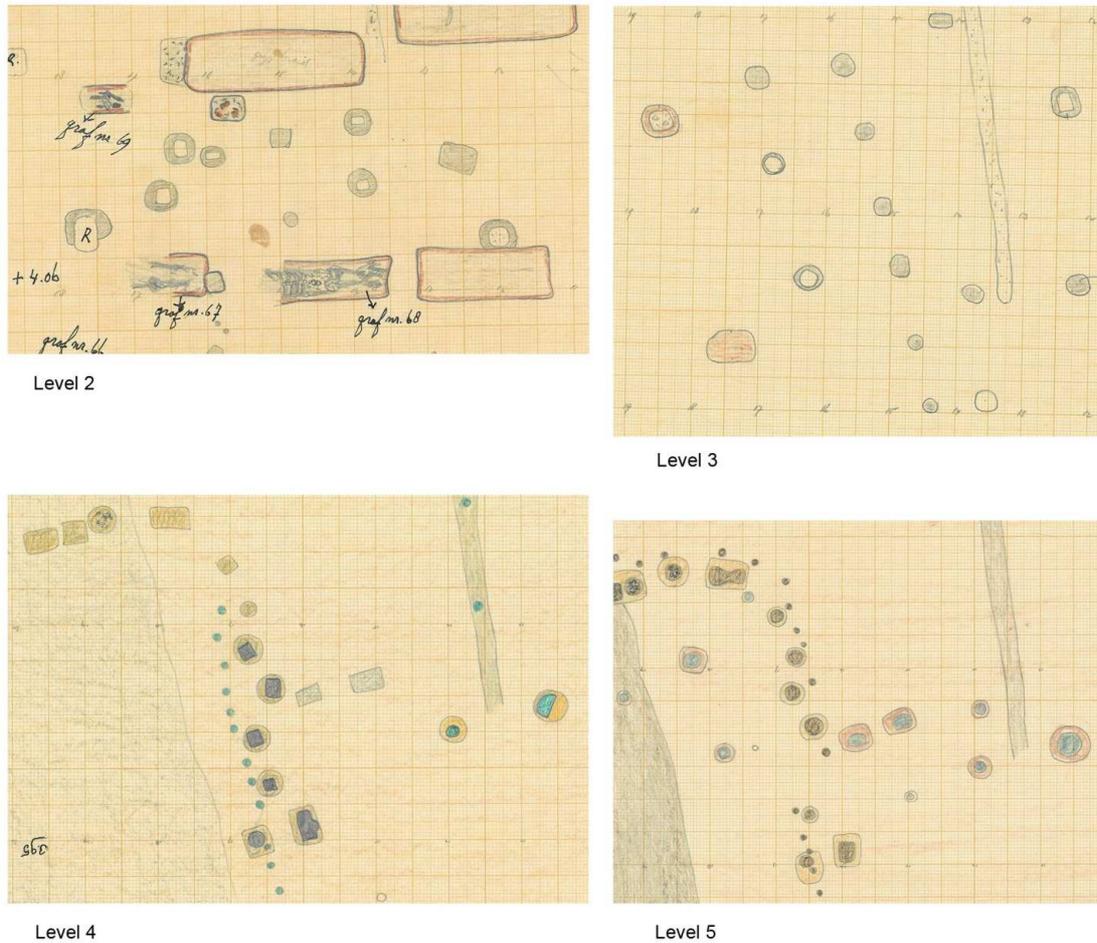


Fig. 5 – Four parts of different levels from trench 136 on the original field drawings. All four depict more or less the same area of the trench in the south-western corner. Substantial differences between the location and shape of features are noticed. It also evident that the field drawings were drawn in different styles by different draughtsmen. The post holes on level three are relatively simply drawn compared to the other levels.

As mentioned above, information on the elevation on the two lowest levels are lacking. To compensate this problem, an elevation value of five centimetres was assigned to different areas in the two lowest levels. This value was based on the average elevation difference between levels in trench 136 and the surrounding trenches. Level 5 is five centimetres below level 4, and level 6 is ten centimetres below level 4.

After all features were given a unique number and the analysis of individual features resulted in pseudo 3D polygons, the features were also described and documented in the attribute table in ArcGIS. In the attribute table the most probable interpretation of the type of feature was recorded. The possible options being: *pit*, *post hole*, *post hole fill*, *ditch*, *irregular disturbance*, *excavation trench*, *unknown* and *other*. The shape of the feature was documented with options being *round*, *square*, *rectangular*, *oval* and *other*. Also the highest and lowest elevation measurements were documented, and consequently the depth was calculated in as a separate attribute field. These attributes were then used to generate the pseudo 3D image, but may also be used to conduct spatial analytical research.

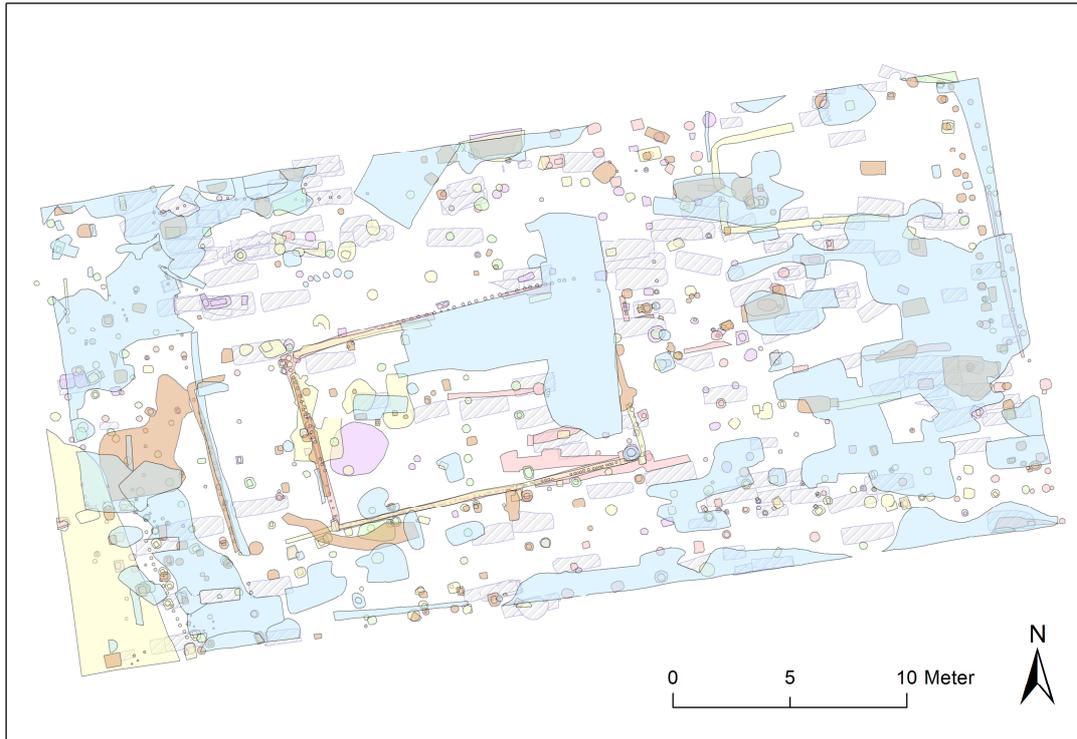


Fig. 6 – An overview of all features in trench 136, in two dimensions, after creating the spatial database. The different colours represent the different levels on which the features were first documented.

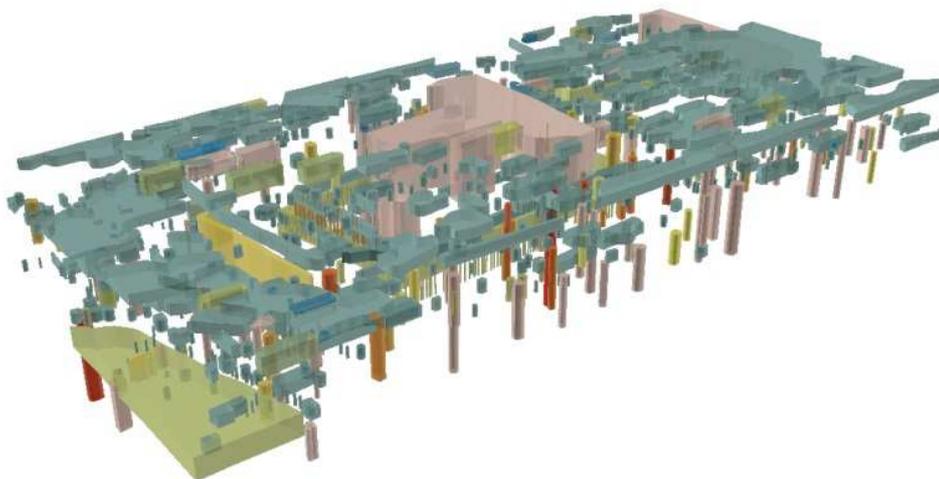


Fig. 7 – An overview of all features in trench 136, in pseudo 3D. Using ArcScene, the image can be zoomed in and out and rotated in all directions. The different colours of the features represent the relative depth of the features. More red means a feature with more depth.

Result and discussion

The pseudo 3D image and the spatial data resulted in a visualisation of all features recorded at different excavation levels. Marking the features with colours on the basis of attributes made it easier to interpret the relation between the different features. This allowed us to group features belonging to the same structure and it elucidated the diachronic sequence of features and structures.

A study to objectively establish the added value of a pseudo 3D reconstruction was not within the scope of our project. Therefore the aspects presented here result more from personal, subjective observations rather than objective observations. Both authors found the resulting pseudo 3D image of great help in creating a spatial image of an excavation that was carried out 40 years earlier. An important factor seems to be the ability to observe the pseudo 3D image from every desired angle. In part the image overcame the disadvantages of the excavation method collecting information in artificial spits or excavation levels.

Creating the pseudo 3D image for the case study presented in this paper took about 80 hours of work.

However, this includes a phase of trial and error figuring out the best GIS method and the drafting of the protocol. Now that the method and the protocol are completed, it is estimated that the whole procedure for a similar trench would take about 40 hours of work. The authors do not believe that there is added value for the application of this approach to trenches with few and uncomplicated features. However, we certainly recommend creating a pseudo 3D reconstruction of trenches of a more complex nature.

The protocol is made to work with data that do not meet modern day criteria. It can only compensate for missing information in a limited way. A detailed interpretation of the recorded features before creating the composite features and the accompanying polygons remains necessary and is the most time consuming part of the procedure.

Conclusion

In this paper a method was presented to use and analyse analogue data in a digital way. The goal was not to use digital archaeology to just make an image of the source data. Rather, digital archaeology was used to develop a research tool which could help to analyse findings that were recorded in the past and are now studied by archaeologists who were not present at the time of excavation.

The process to create a pseudo 3D image from analogue field drawings consists of three steps: digitalisation, describing and interpreting and finally the creation of a pseudo 3D image. In order to reach a reliable and controllable result all features are interpreted and described following a protocol. With the recording of all associated data of each feature in the attribute table of the GIS environment a spatial database is created. This makes it possible to conduct different spatial analytical methods, such as visually differentiating between round and square post holes or marking features with an exceptional depth. These methods and other spatial analysis techniques can be used as a tool to further analyse the trench.

Using the elevation measurements on the height and depth of the different features in the trench, a pseudo 3D environment is created. The purpose of this pseudo 3D environment is to visualise the archaeological data in a way which improves the understanding of a trench. The method is particularly useful for trenches with a high amount of features and a complex stratigraphy and for series of features that belong to one or more structures. The user gains a certain spatial awareness of the features in the trench by moving through

the pseudo 3D space. When looking at the trench in three dimensions and from different angles, the relative position, size, shape and depth of features becomes clear. This spatial awareness allows the user to comprehend and subsequently interpret the features and structures in a straightforward manner. It also facilitates a better understanding of diachronic changes of the features and structures in the trench.

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Abbreviations

RCE Rijksdienst voor het Cultureel Erfgoed (Cultural Heritage Agency of the Netherlands), formerly the ROB

RMO Rijksmuseum voor Oudheden (National Museum of Antiquities)

ROB Rijksdienst voor het Oudheidkundig Bodemonderzoek, today known as RCE

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