Archaeologia Polona, vol. 53: 2015, pp. 603-607

Improving the GIS-based 3D mapping of archaeological features in GPR data

Valeria Poscetti[a, b], **Georg Zotti**[a] **and Wolfgang Neubauer**[a, b]

KEY-WORDS: GPR, GIS, 3D mapping, data visualization

INTRODUCTION

The archaeological interpretation of ground-penetrating radar (GPR) data involves the precise mapping and classification of 3D subsurface features detected by GPR. This is generally performed by digitalizing the GPR anomalies in a GIS environment (e.g., Leckebusch 2001; Neubauer *et al.* 2002) by means of vector features (typically polygons). Both manual processes and semi-automatic methods (e.g., Leckebusch *et al.* 2008; Schmidt *et al.* 2013) can be used to map the subsurface features detected in the GPR data. In most cases, especially for complex archaeological sites, manual processes are preferred as they offer a more intuitive way to "extract" archaeological features in an accurate way. Structures like walls, pillars, pits are easily recognizable to the human eye in a very complex and noisy GPR dataset and they can be mapped with high precision when they are mapped manually. In contrast, automatic and semi-automatic feature extraction methods are not yet sufficiently developed to allow for a precise extraction of complex subsurface structures (e.g., Leckebusch *et al.* 2008).

Among the methods used to display the GPR data, horizontal amplitude maps (so-called time or depth slices), extracted from the GPR 3D data block, are widely used for data analysis in a GIS environment. For example, when using ArcGIS software, the GPR depth slices are usually imported into an ArcMap or ArcScene project as georeferenced TIFF images and displayed on different layers. In a traditional approach, the digitization is usually performed first in the 2D environment (ArcMap) by means of polygons. These are then extruded in the 3D environment (ArcScene) in order to obtain an interpretative 3D visualization of subsurface features. The method is generally very time-consuming, especially if graphically accurate 3D models are to be created.

[a] Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology, Wien, Austria
[b] Vienna Institute for Archaeological Science, University of Vienna, Wien, Austria

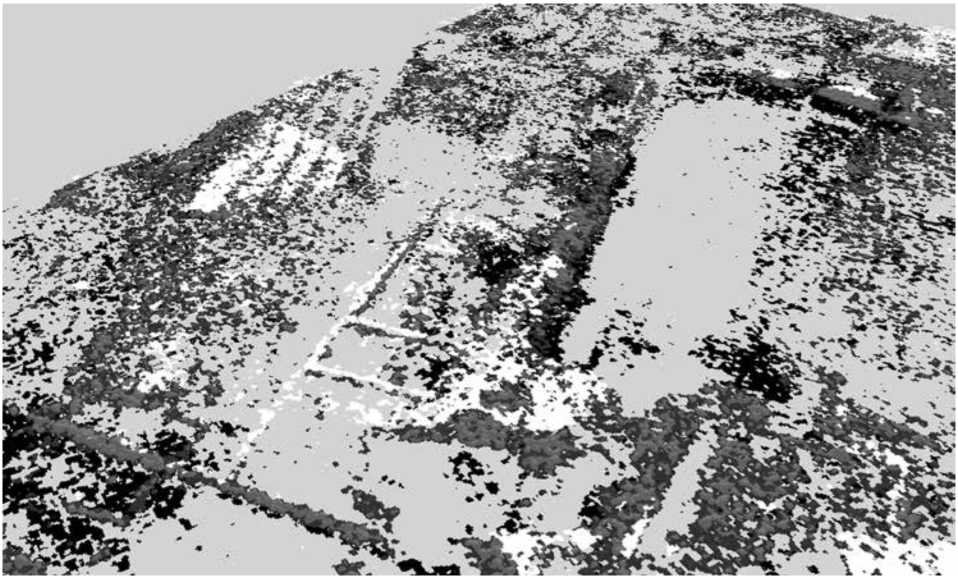

Fig. 1. GPR amplitude maps from different depth levels visualized in ArcScene by setting a "classified display". The shallowest features are represented in light grey, the deepest ones in black

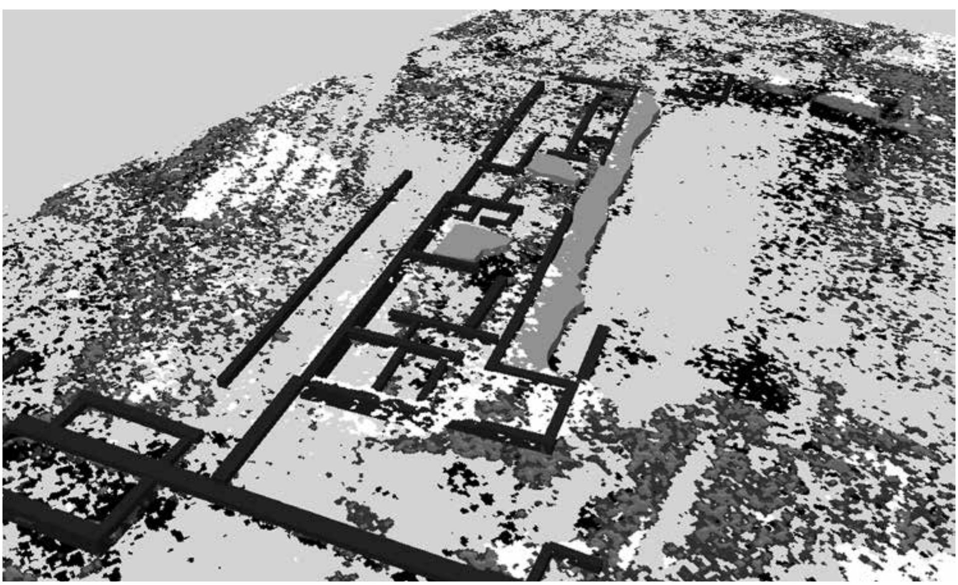

Fig. 2. 3D mapping in ArcScene by means of extruded polygons (1.5x vertical exaggeration)

The paper presents a good method for mapping GPR anomalies in ArcGIS, combining interactive 3D mapping in ArcScene with feature enhancement in GPR raster images.

PROBLEM

One of the main problems in manually mapping 3D subsurface features from 2D amplitude slices is the difficulty in generating rapidly an accurate and easily readable 3D interpretation model of the subsurface features. Even though good practices developed by one of the authors, based on the animated visualization of depth slices in a GIS environment, have greatly improved the interpretation of GPR data (Poscetti 2013), the mapping process remains a fairly complex and time-consuming task.

In a typical approach, features are first mapped in the 2D environment by means of 2D or 3D polygons (with z values in the vertices) that are then extruded in the 3D environment to obtain a 2.5D model. When using ESRI ArcGIS, the extruded polygons can be converted into 3D features (so-called multipatch) resulting in a true 3D interpretation model of the buried archaeological remains. This can be useful, for example, when we need vertically textured objects for a more "realistic" representation of walls, pillars and other elements in our GIS-based three-dimensional map (Poscetti 2013).

Beside the true 3D modeling, which generally represents the final step of the interpretation process, the fundamental problem related to visualization in a 3D environment is that the numerous stacked extruded polygons, resulting from 2D mapping at the different depth levels, in most cases do not offer a clear image of the buried archeological remains. Time-consuming refining work is generally needed to improve the 3D visualization. The problem can be resolved, at least in part, if the features are mapped directly in a 3D environment (ArcScene), in a more intuitive way. Moreover, in relation to the GPR amplitude maps, different types of visualization can be applied, like the so-called "classified display", in which the values of the raster image are grouped into a few main classes, allowing for the enhancing of the most relevant features in the GPR data.

METHOD

In our application, the georeferenced TIFF images displaying GPR data (the abovementioned amplitude maps or depth-slices) are single-band grey scale images using 8-bit unsigned integer cell values (from 0 to 255) to represent different intensities of the reflections (signal amplitude) in a ramp of 256 shades of grey (from 0 [black] to 255 [white]). In our case, the lowest values (dark shades) correspond to the strongest reflections, while the highest values (light shades) correspond to the weakest reflections. The georeferenced TIFF images are imported into the 3D display environment (ArcScene) and displayed on different layers. For each layer, the base height is set according to the depth of the corresponding depth-slice. By considering that relevant features, like stone walls and concrete floors, are generally visualized as dark features (e.g., values from 0 to 100) in a relatively light grey noisy background (e.g., values from 100 to 250), in order to enhance these features, we can group the 256 cell values of the raster into a few main classes and display only the most relevant class of values. By working in ArcScene, this can be done by simply operating on the symbology of the layer. For a slightly better contrast, a so called hillshade display can also be applied to the layer. By conducting the same operation on different depth slices in the ArcScene project, the resulting

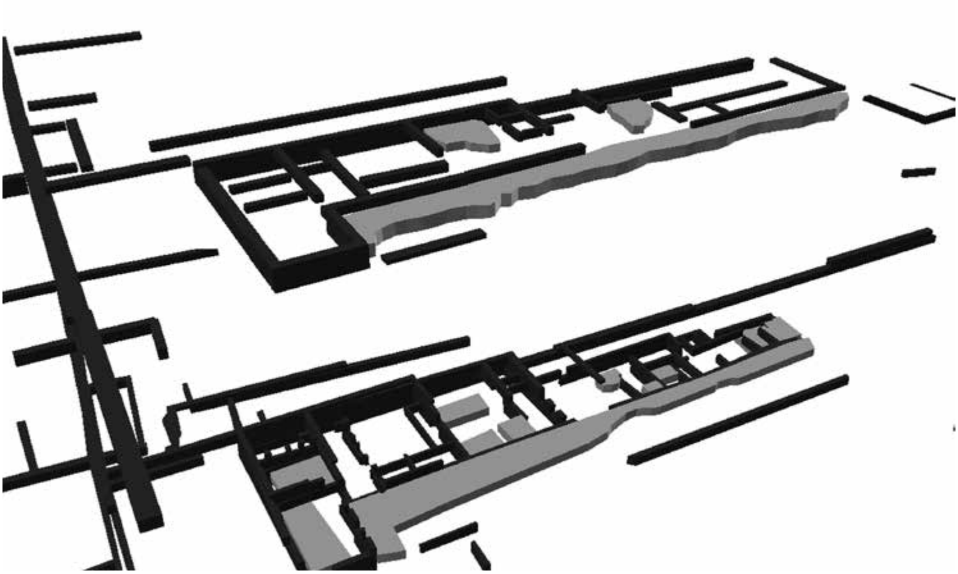

Fig. 3. 3D mapping in ArcScene by means of extruded polygons (1.5x vertical exaggeration: above 3D model in the new approch; below, 3D model in a traditional approach)

image is, apparently, very similar to a 3D visualization through isosurfaces, the fundamental difference being that in our case 3D features were not extracted, but only enhanced as 2D features in the raster images (Fig. 1). The visualization permits the immediate perception of the most relevant archaeological features in a 3D environment, allowing the interpreter to map the features directly in a 3D approach by using a 3D editing tool. The advantage in analyzing the data directly in ArcScene is represented by the possibility to observe immediately the vector features created as extruded polygons and to edit them interactively in a more intuitive way (Fig. 2).

In order to evaluate the efficacy of the method, GPR data from a Roman site in Austria were analyzed independently by two of the authors, respectively with a traditional approach, based on previous mapping in the 2D environment (ArcMap), and a 3D approach, in which the interpreter makes use of classified raster images and directly digitizes the relevant features in a 3D environment.The results were then visually compared in the same GIS project (Fig. 3).

The first interpretation model, even though very detailed and accurate, is affected by a series of small graphic errors in the representation of the Roman structures that become apparent, especially when they are visualized in a 3D environment. The structures mapped in the so-called 3D approach look cleaner and therefore more readable. However, a few details, like internal walls and pillars in the Roman building, represented in detail in the first approach, are missing from the latter model, because they were not clearly visualized through the classified display.

In order to further improve the 3D GPR data interpretation, other methods were also tested by combining the GIS-based 2.5D interpretation models with 3D visualizations of the GPR data, such as isosurfaces. This was made in ArcGIS by importing the isosurfaces into a so-called “multipatch feature class”. Another approach is to export the polygons and visualize them in a volumetric viewer like Voxler, combined with the GPR data block. The polygons can thus enhance the somewhat “foggy” image of the volumetric display.

CONCLUSIONS

The main advantage of the presented method, developed by the first author, lies in the possibility to efficiently obtain accurate 3D interpretation models by simplifying the whole interpretation process. The method can be applied effectively especially in the case of Roman archaeological sites, where numerous high-reflective anomalies, generated from stone walls and foundations, are normally detected. Further improvements of the method should be made by testing more sophisticated feature extraction techniques, to efficiently generate more detailed 3D models.

REFERENCES

Leckebusch, J. 2001. *Die Anwendung des Bodenradars (GPR) in der archäologischen Prospektion – 3D-Visualisierung und Interpretation*. Leidorf, Rahden.

Leckebusch, J.,Weibel, A. and Bühler, F. 2008. Semi-automatic feature extraction from GPR data. *Near Surface Geophysics* 6: 75-84.

Neubauer, W., Eder-Hinterleitner, A., Seren, S. and Melichar, P. 2002. Georadar in the Roman Civil Town Carnuntum, Austria: An Approach for Archaeological Interpretation of GPR Data. *Archaeological Prospection* 9: 135–156.

Schmidt, A. and Tsetskhladz, G. 2013. Raster was Yesterday: Using Vector Engines to Process Geophysical Data. *Archaeological Prospection* 20: 59–65.

Poscetti, V. 2013.Interpreting GPR data in GIS: animation tools and 3D visualization applied to the archaeological interpretation of Roman structures. In In W. Neubauer, I. Trinks, R.B. Salisbury and C. Einwögerer (eds), *Proceedings of the 10th International Conference on Archaeological Prospection. Vienna, Austria, 29.05.-02.06.2013*, 433-435. Vienna.