Scanning Ancient Building Components

GEORG HERDT & MARK WILSON JONES, Bath, UK

Keywords: Ancient Greece, Digital modelling, Ionic capital, Laser scanning, Rapid prototyping, Virtual reconstruction

Summary: The wish to use new technology as it becomes available is normal. The changes that flow as a result are mostly, but not all, for the better; negative consequences run parallel to positive ones, and it is so with the use of laser scanning for surveying. Here we report and comment on a research project at the University of Bath which involves the 3-D scanning of ten Ionic capitals belonging to the archaic Greek period. The scans obtained represent a digital means of recording these objects in their present state, while also providing the basis for creating 3-dimensional virtual reconstructions of them in their original state. The disadvantages and advantages became obvious during the course of the project, as the point-cloud obtained cannot replace all of the traditional virtues of observation, of hand-drawing and of graphic representation (plan, section, elevation). But if the two different techniques are combined together, fascinating results can be achieved.

Zusammenfassung: *3-D Scannen von antiken Bauteilen.* Technische Neuerungen wecken das Bedürfnis, diese zu benutzen, diese Tatsache ist nichts Neues. Die Folgen, die aus ihnen resultieren, sind jedoch nicht immer abzuschätzen; so zieht eine positive Veränderung oft eine negative mit sich, wenn auch in einem anderen Bereich. Im Rahmen einer Forschungsarbeit der Universität Bath wurden zehn ionische Säulenkapitelle mit einem 3-D Scanner aufgenommen und anschließend rekonstruiert. Die Vorteile sowie die Nachteile dieser Methode werden deutlich, sobald es an die Verarbeitung geht. Die Ergebnisse dieser Technik sind andere als die der Bauaufnahme (Aufsicht, Schnitt, Ansicht) und für ähnlichen Gebrauch ohne diese nicht ausreichend. Kombiniert man jedoch diese beiden Techniken, lassen sich faszinierende Ergebnisse erzielen.

1 Introduction

In some ways the surveying and representation of buildings and their components has changed relatively little over the years. We still measure and draw by hand just as researchers have done traditionally, and still use the same conventions of plan, section and elevation that can be found generally in publications on architecture, and also in standard archaeological handbooks on Greek architecture (GRUBEN 2001, HELLMANN 2002). But recently several new techniques have become available, which we use not only because of their accuracy, but also because of their compatibility with computer and information technologies. These modern techniques may refine older ones, or they may replace them. It can be too easy just to adopt new techniques because of contemporary trends, but this should never be done hastily, or out of a wish to 'jump on the bandwagon'. Technological progress means change, and this inevitably is connected with loss. Even if this does not involve the loss of information about the object of research, it involves the loss of traditional craftsmanship and the sensibility associated with it.

2 Advantages and Disadvantages

For the purposes of a research project undertaken at the Department of Architecture and Civil Engineering at the University of Bath, funded by the Arts and Humanities

1432-8364/08/2008/245 $ 1.75

Fig. 1: Naxos, votive column, scan.

Research Council (UK), nine Ionic capitals and the votive column (cf. Fig. 1) from the sanctuary of Demeter at Naxos (GRUBEN 1989) were surveyed with a Minolta VI-910 close range 3-D scanner. This project investigates the early development of the Greek architectural orders (BARLETTA 2001, HELLMANN 2002, WILSON JONES forthcoming), an important subject that is hampered by the varied state of the information that is currently available about Ionic capitals of the archaic period (THEODORESCU 1980). Some are well preserved, some are fragmentary, but in any event all of these complex and sophisticated artefacts have been surveyed and drawn with varying degrees of accuracy. Our desire is above all for consistency, and for this scanning is very well suited. The procedure for acquiring the data in a form that can be processed with modelling programmes is actually quite lengthy, involving a series of separate actions that are set out in Fig. 2.

Scanning and 3-D digital manipulation represents a potential breakthrough, but in order to achieve the best results it is well to be aware of the advantages and disadvantages. The main advantage is the creation of a metrically accurate virtual copy, which is accurate to within small tolerances. This copy can be created without any physical contact with the original object. Another key advantage is the speed with which the scanner works, meaning that a copy can be created in a short amount of time on site (leaving further time for elaboration offsite). The copy can be reproduced as often as required, while the data can also be stored in different locations, acting as an insurance should the original fragment get lost or damaged. This scan provides, as a virtual object, the basis for various kinds of digital manipulation, reconstruction, renderings and so on. Its three dimensional characteristics represent an important enhancement for research purposes. Unlike a photograph, it is possible to zoom continuously in and out, to get closer to the detail required. Areas that would be concealed behind frontal portions in a photograph or drawing can be accessed, just as if the real fragment was 'inside' the computer.

On the other hand there are some disadvantages. These can be kept within reason-

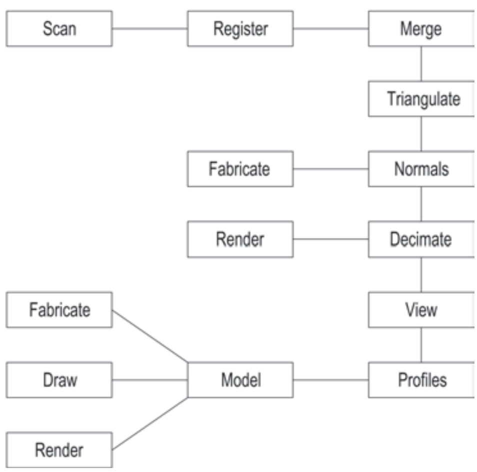

Fig. 2: Workflow diagram for processing information from a scanner and then producing 3-D models and 2-D drawings.

able limits if they are known from the beginning, and steps are taken to supplement the scanning with other techniques such as hand drawings or photographs. Our concern here is not so much technical constraints (e. g., the necessity of working at relatively low light levels, below 500 Lux ideally – far lower than the dazzling levels of daytime illuminance typical of outdoor archaeological sites in the Mediterranean), but with the accuracy with which the scan approximates to the object, because the scan becomes in effect a substitute for the original for study purposes. In fact the most important disadvantage, paradoxically, lies in the very creation of the scan itself. After the object has been scanned, researchers will return to their institution, to work with the virtual copy. The scan of course cannot be the same as the object, it can only be an approximation, one that is conditioned by certain characteristics.

The information we obtain from a scanner exists as a point-cloud. This point-cloud is the quality determining factor. It follows that the more dense the cloud, the more accurate the virtual reproduction. A denser cloud requires more scanning time, but this is not the limiting factor. With a resolution of 0.5 mm–0.8 mm the scanner typically delivered 12 million faces for our group of capitals, equivalent to a file size that was too large or 'heavy' to be manipulated with affordable hardware (especially memory) and software. What use has the densest possible point-cloud if in practice computers cannot handle it? So the resolution has to be kept down to a reasonable limit, 3 million faces instead of the 12 million, and from this follows a series of negative consequences. Small-scale historical traces, such as tool marks, might not be visible at a reduced resolution. It is also important to note that while completely smooth surfaces are clearly distinguishable from rough ones, different kinds of roughness can be hard to discern. Surfaces may be rough because they were originally made rough, or because they were damaged, yet such differences might not be visible from the scan.

The geometrical characteristics of the object are also significant. For example, an object like an Ionic capital may include some surfaces that meet at a sharp arris, such as the darts of the egg-and-dart ornament that run around the echinus. When making careful observations by eye, and perhaps touch, this can become clear, despite the fact that the arris may have been eroded, with the exception of some occasional protected areas. But because a scan registers points generated on a grid, like throwing a net over the capital, it is understandable that only a few points may happen to coincide with surviving parts of the arris. Relying only on the scan, one could have the impression that the ridge of a dart was rounded, missing the fact that it was originally sharp.

To improve the accuracy of interpretation it is therefore necessary to take abundant high-resolution photographs, but even these may not show critical points of information, especially when they are hidden from the view of the camera lens. For this reason we have to draw sketches recording characteristics of interest and referencing them to their location. Even the most modern technologies and the most highly advanced software cannot, and must not, replace the reading and understanding we get from careful observation of the original.

3 Graphic Considerations

After these observations relating to the recording and handling of the data and its limitations, our next concern is with the elaboration of the data off-site. At this stage a procedure has to be put in place (cf. Fig. 2), by which the point cloud is converted into a mesh that can be imported into suitable software programs, in our case Rhinoceros, Nurbs modelling programme for Windows, provided by McNeel Europe (Robert McNeel & Associates 2002). Then questions of representation come to the fore, and also of the reconstruction of the object in its hypothetical original ideal state.

Regarding representation, a key challenge for any new technique is to adapt itself to the conventions of publication and study.

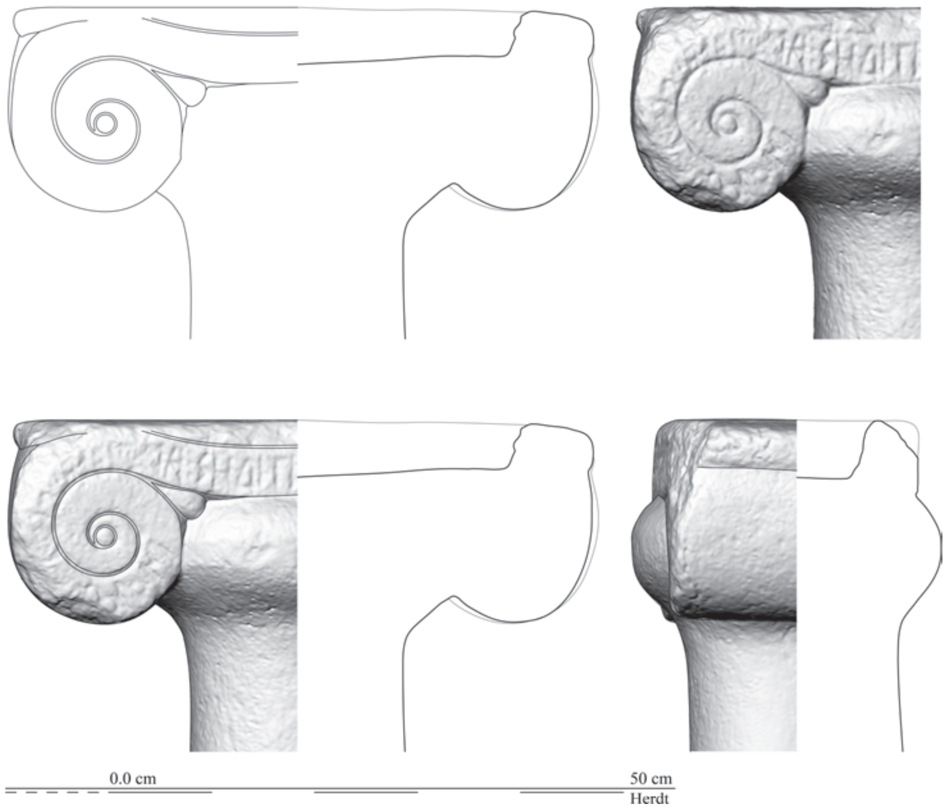

Fig. 3: Naxos, votive column, elevations and sections with scans.

This still requires the creation of traditional drawings in the form of plans, sections and elevations. Before this can be done the side to be drawn has to be orthogonal to the viewing plane. Then the scan is qualified to serve as a background image for tracing via the use of a 2-D programme. The representation of the scan (which presents itself as surfaces) in the form of an elevation made up of lines involves decisions and judgement, just as in the case of drawing an object traditionally. The question of style is of course a matter of personal preference or taste. Should we lose the delicate information-rich qualities of the hand drawing, which did such a good service over so many years? The superimposition of scan and projection just mentioned also raises the possibility of new types of hybrid image, in which the intensity of the scan background can be adjusted as desired (cf. Fig. 3). Using this technique it is possible to convey convincingly roundness and other volumetric characteristics that are problematic by means of line drawing alone.

Cross-sections may be created in a similar way to the drawing of elevations. Here the main advantage of the 3-dimensional scan comes into play; any cross-section at any chosen location can easily be split off from the other parts, highlighted and drawn as a 2-dimensional profile. The scan resembles a picture, but with the benefit of containing 3-D information, with infinite possibilities for subsequent interrogation. This is quite different from the 2-D outcomes of traditional surveys, by which the researcher returns to his or her place of work with only a limited number of profiles.

4 Reconstruction

When turning to 3-dimensional reconstructions (cf. Fig. 4), their creation from the scan is not simple; it cannot be done by pressing a button, in fact the model has to be created line by line, surface by surface, each with its individual shape. As in the case of making the sections, the scan can be interrogated for profiles wherever one wants, by splitting the mesh as often as necessary. After the profiles are redrawn, the model can be created from them. Just as the original may have been broken or incomplete, so too is the scan, leaving room for interpretation. Trial and error is an important part of the process, with many more possibilities for reversibility than when fragments are integrated using plaster. For such work the knowledge and experience of the person doing the reconstruction is inevitably the quality determining factor, yet the 3-D scan is able to enhance the level of quality, because it can be compared with the reconstruction at any level of detail, unmercifully showing any deviations. In some way it is as if the reconstruction is 'wrapped' around the scan. At positions where the reconstruction is too far from the scanned surface a gap appears, or, if the reconstruction is too close to the scan, or actually within it, the two surfaces intersect. With patience an accurate model, within the tolerances we choose to work with, can be made with negligible differences between the reconstruction and the original. In other words the reconstruction becomes a virtual replica of the hypothetical ideal or undamaged original.

Fig. 4: Naxos, votive column, reconstruction.

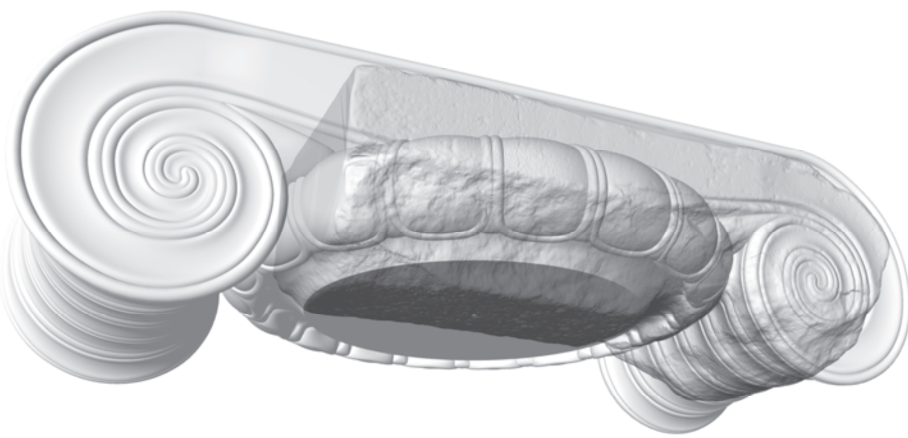

Fig. 5: Naxos, Yria, frontal capital of the Dionysos-temple, superimposition of scan and reconstruction.

For the visualisation which comes at the end of the modelling, different possibilities are available. The original scan (cf. Fig. 1) and the reconstruction (cf. Fig. 4) can be compared, either in the form of prints or video, or simply on the screen. It is useful to show together in the same file the original scan and a semi–transparent reconstruction, as in the case of the visualisation of a capital (cf. Fig. 5) from the temple of Yria, Naxos (Gruben 1991, Ohnesorg 1996). This differentiation is extremely effective, since it reveals several things at the same time:

- the extent of preservation of the artefact compared to the original state
- the fidelity of the reconstruction compared to the scan
- the quality of the modelling.

For the purpose of creating elevations certain aspects of the model do not have to be perfectly resolved, especially anything that lies behind the surface viewed in elevation. But changing the object properties to transparency introduces a technical challenge. From now on every part that would usually be hidden behind the surface becomes visible. To avoid confusing, overlapping or unnecessary pieces, the model has to be created extremely carefully. It is best to create a single, 'watertight' object, with all surfaces perfectly joined to their neighbours.

With watertight virtual objects another new possibility is available. A rapid prototyping machine allows us to print the computer model as real haptic models, as in the case of the votive column (cf. Fig. 6) of the Naxians at Delphi (Amandry 1953), using a variety of materials (depending to the budget). The one illustrated in Fig. 6 was made of a relatively cheap plaster-based medium.

5 Conclusions

The possibilities offered to us by the new technologies described in this paper, such as the ability to superimpose scans and reconstructions (cf. Fig. 5), or to 'print' in 3-D (cf. Fig. 6), promise to advance archaeological research in exciting ways. However, as we mentioned earlier, the benefit of technology can still be enhanced by traditional drawing techniques and observation. Indeed these remain vital if information about an object is not to be lost or misrepresented in creating the virtual copy. The process of modelling is not just a mechanical exercise, it requires interpretative skill and artistic or architectural sensibilities. So far we have no machine invented that is able to replace the qualitative analysis of thinking human beings.

Acknowledgements

We would like to thank The Scan Team (www.thescanteam.co.uk), and in particular Mark Phillips, who acted as subcontractor

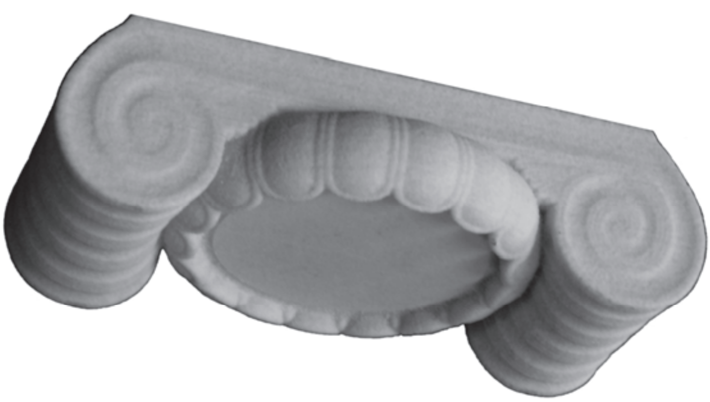

Fig. 6: Delphi, capital of the Sphinx of the Naxians, model created by rapid prototyping.

on this project. We are also grateful to David Scahill and Maria Pilali of the American School of Classical Studies in Athens for arranging the permits kindly granted by the Greek authorities. David Scahill and Mantha Zarmakoupi also provided valuable logistical support during the field trip itself.

This research depended fundamentally on Professor Paul Richens, who was instrumental in setting up the project and resolving the full range of technical issues involved in carrying it out. Paul Shepherd's mathematical expertise was invaluable in helping us with decimation and other processes prior to modelling.

References

Amandry, P., 1953: La Colonne des Naxiens et le Portique des Athéniens. – Fouilles de Delphes, Tome II, Topographie et Architecture, De Boccard. Paris, France.

Barletta, B., 2001: The Origins of the Greek Architectural Orders. – Cambridge University Press, Cambridge, UK and New York, USA.

Gruben, G., 1989: Das älteste marmorne Volutenkapitell. – Istmitt **39:** 161–172.

Gruben, G., 1991: Anfänge des Monumentalbaus auf Naxos. – Bautechnik der Antike, Hrsg. A. Hoffmann – Philipp von Zabern, Berlin, Germany: 63–71.

Gruben, G., 2001: Griechische Tempel und Heiligtümer. – 5. Aufl., Hirmer, München, Germany.

Hellmann, M. -C., 2002: L'Architecture greque 1, Les principes de la construction. – Picard, Paris, France.

McNeel, R. & Associates, 2002: Rhinoceros. – NURBS modeling for Windows. Version 3.0 User's Guide, Seattle, USA.

Ohnesorg, A., 1996: Votiv oder Architektursäulen. – Säule und Gebälk, Hrsg. E.-L. Schwandner, von Zabern, Mainz am Rhein, Germany: 39–47.

Wilson Jones, M., forthcoming: Gifts to the Gods. The conception of temples and orders in ancient Greece. – Yale UP, London, UK.

Theodorescu, D., 1980: Le chapiteau ionique grec. – Essai monographique, Paris, France.

Address of the Authors:

Dipl.-Ing. Georg Herdt & Mark Wilson Jones, Department for Architecture & Civil Engineering, University of Bath, Bath BA2 7AY, UK, e-mail: g.herdt|m.w.jones@bath.ac.uk.

Manuskript eingereicht: Januar 2008
Angenommen: Mai 2008