DIGITISING ANCIENT POTTERY. PRECISION IN 3D

The base of each science, in particular of archaeology, is a thorough documentation. Hence, the discussion about the best methods and tools of documentation – this includes the recording of ancient pottery – lasts as long as archaeological research itself. On the one hand, pottery often acts as "Leitfossil" of a stratum in archaeological excavations and helps fundamentally in dating the stratigraphical records. Beyond this aspect ceramics are significant for questions concerning trade, the transfer of technologies and so on. On the other hand, especially painted and decorated pottery is stored in private and public collections due to their artistic value; its original context is disturbed, but it still holds valuable information on technology and art history.

In early times of archaeological research, a skilful drawing and a verbal description was sufficient in order to publish ancient pottery. In the second half of the 19th century the newly developed photography challenged these traditional methods. After photography was established in archaeological publications, at that time expensive and time-consuming, the emerging colour photography again provided an impetus to discuss and rethink archaeological documentation. Recently, digital photography once more changed the parameters and offers new possibilities. Today, the pictorial documentation seems much easier and cheaper; also its dissemination is enhanced by modern communication technologies. Each newly developed method improved the results and enriched the information about the ancient objects; simultaneously documentation standards are adjusted to the new methods. [1] Nevertheless, pursuing serious science is as challenging as ever.

Means of Documentation of Pottery in the Digital Era

Why not taking a step forward again? The digital era provides various new means for documentation in different fields of archaeological research. In this paper we'll focus on pottery research and are going to discuss the pros and cons of documentation by a 3D scanner. [2] Basically, choosing a computer based measuring device differs not fundamentally from a conventional measuring system: accuracy, gentle handling of the ancient artefacts and cost-effectiveness are highest priorities.

For more than two centuries the conventional method for the documentation of a vessel's shape is the so-called profile line, which in general shows a vertical cut through the oriented sherd or pot. Usually a frontal view and an intersection of the body are combined in one drawing in the publication; additional sections, i.e. of handles, or top views may be revealing. Nowadays, the figural or ornamented surface is usually depicted by additional photos, if necessary supplemented by sketches of underdrawings, engravings or any other special features of a pot, i.e. coloured or restored parts. Moreover a detailed verbal description is essential for complete documentation.

Using a 3D scanner enables us to earn additional information on an ancient vessel. Therefore, this technology is used more and more in pottery research (see below). Unfortunately, faith in technology often leads to overestimating the possible results and consequently to the users' disappointment by the output. Besides that, computed 3D models are inappropriate for traditional publication schemes, like printed books. [3] But, measurements by a 3D scanner offer various ways of presentation and publication, useful not only for scientific but also for educational purposes. On the whole it can be said, that the full potential of 3D models is not exhausted so far; therefore and due to various other reasons, 3D data is often not accessible to the public and ends up as graveyard data.

Principles of 3D Acquisition using a 3D Scanner

A complete documentation of ancient pottery requires the recording of the colour and three-dimensional shape, both with high resolution and data quality. In order to record the large number of artefacts with a reasonable effort, the scanning technology should allow an automated data acquisition and processing with a spatial resolution of up to 50µm. A special challenge for any digitisation process results from the surface characteristics of pottery: the surface colour varies from white to very dark with slightest nuances in hue and saturation; moreover especially the dark areas can be highly reflecting.

The most suitable scanning technology to fulfil these requirements is the fringe projection technique. [4] These topometric 3D scanners have been successfully used for a wide range of cultural heritage objects since about 15 years. [5] An adaptable field of view, resolution and accuracy ensure optimised results for various special applications. Thus, it is possible to scan single fragments as well as complete vessels with the same equipment. In combination with an automated turn-table they allow fast data recording of fragments from sizes of a few cm up to half a meter. Each side of a fragment is scanned from about 6 different angles. The single scans are automatically registered and in the following merged into one 3D model.

	smart*SCAN*^{3D} 5C
Camera type	2 CCD colour cameras
Camera resolution	5 MPixel, each
FOV	30 to 1500 mm
Operating distance	250 to 1500 mm
Triangulation angle	3 triangulation angles (30°/20°/10°) within one setup
Acquisition time	ca. 1 sec (fastmode)
Sensor weight	ca. 4 kg
X/Y resolution	10 to 500 µm
Z resolution	2 to 50 µm

The table shows the main specifications of a modern topometric scanner, the smartSCAN^{3D} 5C system from Breuckmann. The integrated colour cameras of this high definition 3D scanner allow a synchronous acquisition of colour and shape with a special High Dynamic Range technique adapted to fringe projection technique.

New Development in the 3D Scanner Technology

One major challenge in the documentation of pottery results from the fact, that large parts of the surface are nearly black and very shiny. For this reason even in 2D imaging one has to control the illumination conditions very carefully to avoid strong reflections. 3D scanning documents the object from different viewing directions; therefore a very homogenous and diffuse illumination is essential in order to avoid direct reflections and to assure that there are no changes in colour information when recording the same surface area from different angles. Nevertheless, even with the most sophisticated illumination one cannot completely avoid small variations in colour of surfaces, which are both black and shiny.

However, combining that different colour information recorded from the various viewing points would cause so called artefacts and distortions of the resulting 3D model. Therefore we have started to develop new software tools, which are able to detect and correct reflections and colour changes in the single scans. Although we do not have a final solution yet, which automatically overcomes all kinds of the resulting distortions these new approaches show very promising results.

The colour representation recorded and analysed with this technique is highly comparable to a 2D photography.

Further Use of 3D Data

Scanning or digitising is extremely popular nowadays. These methods are applied not only to archaeological artefacts of cultural heritage, but also to precious manuscripts or rare printed books of the last centuries. No doubt, our world is going digital but it seems it is doing so more or less without strategic plans. No one asks for long-term preservation and questions the origin of the collected data or how the digital models have been calculated at all. Finally we will be confronted with a mass of 3D models and visualisations and we will face the serious problem to define the relation between the real object and the virtual “copy”. Are we creating our own virtual past? Without traceability of the whole procedure of digitisation the data will be unusable and must therefore be considered as lost in the future. There is still a lot to be done. Nevertheless, these techniques and methods in 3D digitisation open up new grounds in humanities by generating additional information about artefacts and by providing new opportunities in documentation, analysis and presentation of cultural heritage; especially of ancient pottery – the subject of this overview.

3D models of ancient pottery offer a wide range of further use, scientific and public ones. Choosing the optimal technique, the resolution and the time to invest depends on the requirements, which the 3D data has to fulfil in further procedures. Pottery research in particular requires reconstructing a 3D model as accurate as possible, both in terms of geometry and texture. [6]

In order to gain cross-sections through vessels 3D data was systematically applied in a publication project about ancient vases for the first time. [7] Such profile lines can also be taken in conventional ways, which is often faster and sufficiently accurate for archaeologists. In receiving the complete three-dimensional account of the surface, it additionally enabled to determine the capacity of a vessel, virtually filled to a certain level. It would be technically possible to calculate the ceramic’s volume with this method, which is relevant for the determination of the bulk density of the material. Based on a larger amount of data it opens up possibilities of comparisons of certain Greek vase shapes, using these results for typology and shape development. [8] 3D documentation is already used to determine manufacturing techniques of pottery. [9] Scanning the complete vessel in 3D and then publishing a profile only is to break a butterfly on a wheel. Other media than a printed book are strongly in demand to use these data adequately.

Using principles from geographical information systems and map projections 3D data of the surface can be unrolled. This documentation of unwrapping is particularly suitable for painted surfaces, which are not recorded in their entirety by photography from one point. [10] For scientific proposes in archaeology, but also in common visualisation, these rollouts are still lacking the required resolution of the texture.

The main part of pottery research deals with fragments. Concerning wheel-made pottery 3D data enables to automatically determine the original radius of the whole object. Further, information of the orientation of the fragment will be provided based on the reconstructed portion of the preserved rotational body. [11] This method is highly effective, but is still missing comfortable software solutions for users who are not trained in informatics.

In the field of putting fragments together the development of automatic or semiautomatic virtual assembling methods would be of greatest interest. There are already first attempts in this direction [12], but the reconstruction of the original vessel from such artefacts is a problem of greatest complexity. We consider that an interdisciplinary attempt (humanities, informatics and mathematics) can meet this challenge.

A further area of application is to support interactive models of digitised artefacts for public use i.e. at museums and exhibitions, which is used very little so far. Virtual visualisation can be used to improve the understanding of museum objects. The 3D data may be materialised easily, in almost any material. The 3D print technology enables a reproduction of artefacts in an arbitrary scale (original, en miniature or enlarged), even with the original painting. Furthermore it allows the complement of the vessel based on scientific knowledge, if fragments are missing.

Conclusions

The acquisition of geometry in combination with texture and the effectiveness of the scanning process are sufficient for most of the tasks. High resolution scans provide good results for the scientific research. 3D scanning offers many advantages compared to conventional documentation: non-contact measurement, accuracy, freedom of scale, and efficiency. 3D models provide additional information, which could not be gained by other means: calculated positioning of fragments, capacity, volume of the ceramic material, and virtual assembling of dislocated fragments. Digitising objects of Cultural Heritage, including ancient pottery, is still ongoing, but we urgently need to establish guidelines to ensure the quality and sustainability of scanning data.

[1] On the working with photos and profile drawings cf. H. Mommsen, Zur Auswertung von Formfotos und Profilzeichnungen, in: M. Bentz (ed.), CVA Germany Beih. 1 (München 2002) 23–36.
[2] Despite the technical progress, modern equipment (microscope etc.), and physicochemical analytical techniques, the absolutely essential first hand observation of objects is not to be forgotten; B. Cohen (ed.), The Colors of Clay (Los Angeles 2006) 6; J. Boardman, The Study of East Greek Pottery, in: A. Villing – U. Schlotzhauer (ed.), Naukratis: Greek Diversity in Egypt. Studies on East Greek Pottery and Exchange in the Eastern Mediterranean, British Museum Research Publication 162 (London 2006) 49–52; 51: „We shall still have to rely on judgement by eye most of time – (...)".
[3] The technology of a 3D scanner is based an optical laws. Radiographic methods, i.e. X-ray pictures, computer tomography, can reveal even more information; cf. E. Trinkl (ed.), Interdisziplinäre Dokumentations- und Visualisierungsmethoden, CVA Austria Beih. 1 (in press).
[4] K. Creath, Phase-Measurement Interferometry Techniques, in: E. Wolf (ed.), Progress in Optics 26 (North-Holland 1988) 349–393; B. Breuckmann, Bildverarbeitung und optische Messtechnik in der industriellen Praxis (München 1993); C. Bathow – B. Breuckmann – R. Scopigno, Verification and Acceptance Tests for High Definition 3D Surface Scanners, in: A. Artusi – M. Joly-Parvex – G. Lucet – A. Ribes – D. Pitzalis (ed.), The 11th International Symposium on Virtual Reality, Archaeology and Cultural Heritage (VAST 2010), Paris, September 21–24, 2010 (Goslar 2010) 9–16.
[5] Especially stone monuments have been scanned, e.g. C. Bathow – M. Wachowiak, 3D scanning in truly remote areas, The Journal of the Coordinate Metrology Systems Conference (CMSC) 3, 2008, 4–9; C. Bathow – B. Breuckmann, High-definition 3D acquisition of archaeological objects. An overview of various challenging projects all over the world, Proc. of the XXIII CIPA Symposium, Prague, 12/16 September 2011, http://cipa.icomos.org/fileadmin/template/doc/PRAGUE/026.pdf (10.03.2013); A. Schäfer – H. Mara – J. Freudenreich – C. Bathow – B. Breuckmann – H.-G. Bock, Large Scale Angkor Style Reliefs: High Definition 3DAcquisition and Improved Visualization using Local Feature Estimation, Proc. of 39th Annual Conference of Computer Applications and Quantitative Methods in Archaeology (CAA), Beijing, China, 12–16 April 2011 (forthcoming).
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[7] C. Lang-Auinger, Corpus Vasorum Antiquorum – das österreichische Projekt, Forum Archaeologiae 46/III/2008 (http://farch.net); H. Mara – E. Trinkl – P. Kammerer – E. Zolda, 3D-Acquisition of Attic Red-figured vessels and multi-spectral readings of white ground lekythoi in the Kunsthistorisches Museum Vienna, in: K.T. Biró – V. Szilágyi – A. Kreiter (ed.), Vessels: Inside and Outside, Proc. of the Conference EMAC '07, 9th European Meeting on Ancient Ceramics, 24–27 October 2007, Hungarian National Museum Budapest (Budapest 2009) 21–28; E. Trinkl, Attisch rotfigurige Gefäße / Weißgrundige Lekythen, CVA Wien, Kunsthistorisches Museum 5 (Wien 2011).
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