Surface scanning - New Perspectives for Archaeological Data Management and Methodology?

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Abstract

Documentation and publication of palaeolithic objects such as lithic artefacts, bone tools or mobile art is done since decades mainly by drawings. These drawings are an indispensable part of scientific research and methodology. Teaching drawing techniques is even integrated into the educational program at university level. Although creating a drawing is very time consuming and requires training, until now it has not been replaced by photography. Taking a picture of a palaeolithic object is obviously even more difficult than to make a drawing. To visualize all scientific relevant features of an object in just one shot is not possible. The cost/performance ratio for drawings is therefore better than for photography. Photos are used mainly to present objects to a broad public. Within the scientific community drawings are the most frequent medium of information transfer.

Surface scanning of palaeolithic objects has the potential to substitute drawings as medium for scientific information transfer. Polygon meshes are of high scientific value because they allow an objective record of the object and its digital measuring. Once recorded, the digital data file can be transferred via internet and allows direct access to objects. Prehistoric archaeology will have to adapt to this new recording technology and in the future data bases like NESPOS which allow world wide access.

***Key words**: surface scanning, archaeological data management, documentation of palaeolithic artefacts, NESPOS*

1 State of the art

Drawings have the advantage that they follow defined conventions and perform the technical status of an object. This facilitates their sensing, allows quick visual comparison of various items and the information to be put into a larger scientific context. The sensing of drawings of lithic artefacts works at even higher speed than exploring the originals themselves. Items of mobile art are different, though. They present more complex visual information than lithic artefacts and are therefore still the field of specialised illustrators.

An obvious problem of scientific drawings is a loss of objectivity. Ultimately, each drawing is an individual interpretation. By skilfully dispensing or adding minor features, the unambiguousness of an item can be manipulated. This is often the case when for instannce a decision between geofact and artefacts has to be made.

Another problem is the reduction of complex artefacts into a 2D-format by drawing it. Especially pieces of mobile art display a great variety of forms, from basrelief to sculpture. In many cases, the tracing of engravings displaying different line thickness and line deepness is important for understanding a depiction. The same is true for rock art. Drawings do not allow direct access to these details.

Drawings do have another disadvantage. They are difficult to use in the secondary analytical process by the scientific community. Usually, drawings are published in papers or books as main medium of diffusion. In most cases, this presentation only allows a reduced application. Formats are small; the metric of items is difficult to record. All kinds of metric analysis such as calculation of areas, angles or distances are not possible, and therefore the comparison of objects is difficult.

This is why researchers are looking for alternatives. Various laser scan applications have been tested recently[1,2,3,4,5,6]. Especially 3D-surface scanners can cover a wide range of objects and resolutions. Compared with high resolution digital microscopy[7], they produce data sets that can still be managed using standard computer hardware.

2 3D surface scanning

A new generation of topometrical high definition 3D-surface scanners, based on fringe projection techniques and optimized for the requirements of arts and cultural heritage, allow the 3-dimensional digitization of archaeological findings with highest resolution and accuracy [8,9,10,11,12].

Moreover, the texture and/or color of the object can be recorded, offering a one-to-one correspondence of 3D coordinate and color information. Important parameters of the system configuration such as field of view (FOV), triangulation angle and resolution can be defined by the user in accordance with the application requirements.

Figure 1: 3D-surface scanner smart*SCAN*[3D]

State of the art systems are equipped with digital cameras of up to 5 MPixel, offering spatial resolutions for small FOV´s down to 10 µm (according 2.400 dpi for flat surfaces) and depth resolutions of a few µm. Due to the high flexibility and mobility of these systems, they are ideally suitable to be used for a number of different applications. To overcome two of the most critical limitations of optical triangulation systems, special system configurations and recording techniques

[1] T. Barnett et al., "3D-laser scanning for recording and monitoring rock art erosion," *International Newsletter on Rock Art* 41 (2005): 25.

[2] Q. Borderie et al., "3D modeling of paleolithic tools" (paper presented at the workshop on archaeology and computers, Vienna, Austria, November 3-4, 2004).

[3] W. Fitzhugh and J. Bayarsaikhan, ed., *American-Mongolian deer stone project: field report 2007*. (Washington and Ulaanbaatar: Smithsonian Institution, 2008).

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[8] D. Akca et al., "High definition 3D-scanning of art objects and paintings," in *Optical 3-D Measurement Techniques VIII*, ed. by A. Gruen and H. Kahmen (Zürich, 2007), 50-8.

[9] R. Beaubien et al., "Documentation of Mongolia's deer stones," *Project Summaries 2006* March 1, 2007,: 86.

[10] Ch. Bathow, and M. Wachowiak, "3D scanning in truly remote areas," *The Journal of the CMSC* 3 (2008): 4.

[11] B. Breuckmann et al., "High definition 3-dimensional scanning and printing technologies in arts and cultural heritage, archaeology and palaeontology" (paper presented at the EVA, Berlin, Gemany, 2007).

[12] Ch. Hemm-Herkner, "Einsatzmöglichkeiten von 3D-Scannern in der Paläontologie und deren Anwendung," *Der Präparator* 35 (2007): 24.

can be used. First, an asymmetrical 2-camera setup allows the realization of 3 triangulation angles in one sensor configuration (see fig. 2). An intelligent data management prefers 3D-data recorded with the largest triangulation angle,, thus offering best data quality and reliability. Only in case these are not available – meaning that the corresponding object area is seen by only one camera - the smaller triangulation angles are used for the calculation of the 3D-data.

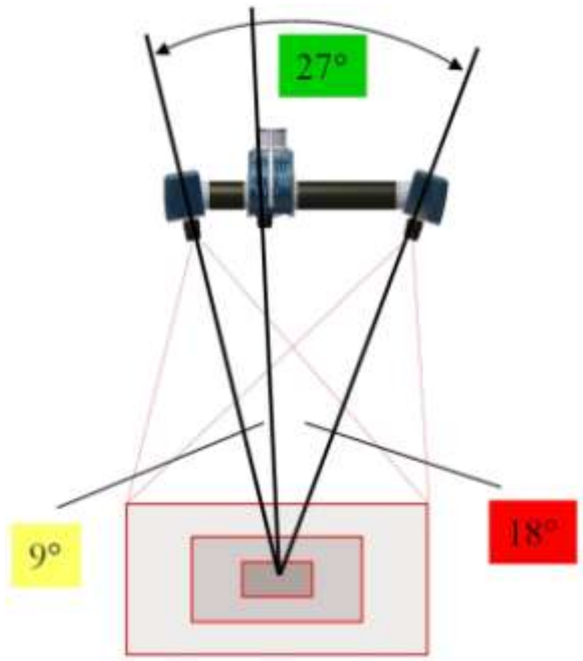

Figure 2: Asymmetrical 2-camera setup.

Moreover, a modified High Dynamic Range acquisition technique is used for recording data on shiny surfaces or for objects with strong differences in reflectivity. Figure 3 shows an example of the digitization of a black Obsidian.

Another important advantage of topometrical 3D-scanners is the fact, that they offer an imaging acquisition of 3D-data. Therefore, 3D-data recorded from different sensor positions or orientations can be aligned to each other by using the 3D-geometry of the object itself. A high accuracy positioning system (e.g. co-ordinate measuring machine, articulated arm, optical tracker) for moving the object or the sensor is not required. This makes topometrical 3D-scanners particularly suitable to be used in museums and for in-the-field applications.

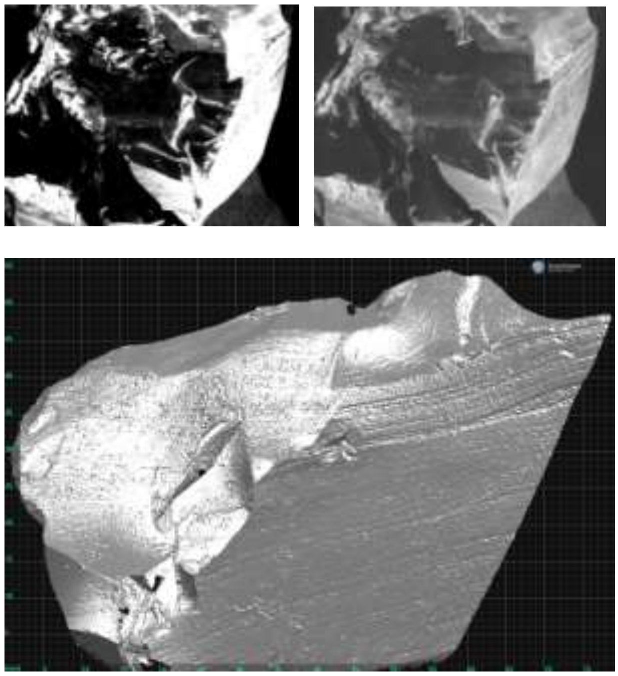

Figure 3: Digitization of an obsidian with a modified High Dynamic Range technique.
left : conventional 2D-image
right : 2D-image recorded with HDR
below : visualization of recorded 3D-data

Considering the outlined methodological background and the improvements in the 3D-surface scanning techniques we decided to use 3D-surface scanning and the resulting 3D-models as base for the documentation of archaeological findings. We carried out a test run and scanned a set of prehistoric items, mainly from palaeolithic context at the Museo de Prehistoria y Arqueología de Cantabria, Santander (Spain). We tested a great variety of objects of different material, dimension and surface structure, including lithic artefacts, rock art and mobile art. Basic idea was to cover all potential modes of application.

3 The scanning equipment

For scanning the different kinds of objects we used two different surface scanners of the Breuckmann GmbH: The smartSCAN^{3D} system (see fig. 1), which allows to scan objects with HighDefinition incl. color and texture as well as a prototype system of a multi-spectral 3D-scanner, which offers 3D-scanning in different wavelength ranges from close to IR to deep blue.

Table 1 summarizes the specifications of these 3D-scanners.

	smart*SCAN*^{3D}	**MSS-3D**	
field of view (FOV)	600 mm	100 mm	50 mm
camera	2 x 1.4 MP color	1.4 MPixel b/w	
light source	100 W halogen	100 W halogen with spectral filters	
sensor weight	4 kg	2 kg	
operating distance	700	340	
acquisition time	1 sec per scan		
X,Y-resolution	350 µm	60 µm	30 µm
depth resolution	15 µm	4 µm	2 µm

Table 1: Specifications of the used surface scanners.

4 Results

Our preliminary results are convincing. Scanning large objects like schematic engravings on stone steles from the late copper age / early bronze age context as well as small-sized examples of upper palaeolithic mobile art could be documented in a short space of time and at high resolution. All features of the objects were clearly visible by using polygon-meshes of the scans and digital measuring of the features where possible with e.g. ArteCore, a software package of NESPOS (www.nespos.org).

The same positive results could be achieved for stone tools. Highly elaborated solutrean points covered by very fine retouches were completely recorded, as well as cores for blades or flakes.

4.1 Rock art: the Sejos stele

As a famous and most interesting example of rock art we have scanned a prehistorical stele from the site Sejos in the mountains of Cantabria. The stele measures about 3 x 1 m, featuring pecked and deep graved lines which are unfortunately strongly eroded nowadays; the engravings are therfore only visible very diffusely.

We have scanned the stele with the smartSCAN^{3D} system with a FOV of 600 mm. A tent was used to keep out the direct sunlight. With no electricity in the mountains, the system was operated by the help of a small 600 W power generator. The complete scanning was realized with 40 single scans in about 90 minutes. Figure 4 shows the location in the mountains of Cantabria, the site with the Sejos monument and the scanning equipment.

Figure 4: Scanning of the Sejos stele in the mountains of Cantabria.

The new 3D-scans open new views on the Sejos monument and on details, which are impossible to realise by using conventional methods, e.g. the zig-zag-lines or the form of the dagger, which is important for the chronological interpretation as a middle bronze age stele (see fig. 5).

4.2 Rock art : the Zurita stele

The Zurita stele, featuring a diameter of more than 2 m, has been scanned in the Museo de Prehistoria y Arqueología de Cantabria, Santander. Using a smart*SCAN*^{3D} with a FOV of 600 mm, it took about 16 scans and 30 minutes to digitize the central part of the stele, measuring about 1,5 sqm, (see fig. 6 and fig. 7).

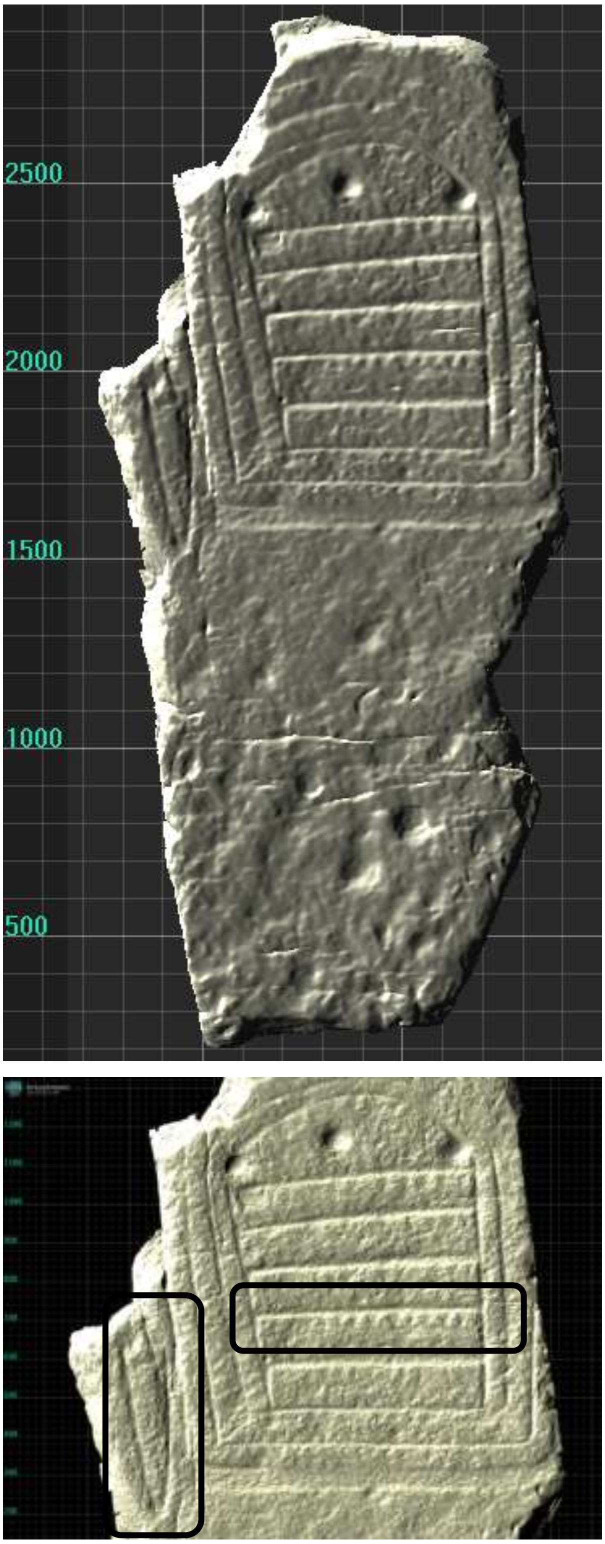

Figure 5: Visualization of 3D-data; to be noted is the form of the dagger and the zig-zag-lines.

Figure 6: Scanning the Zurita stele.

Figure 7: Visualization of the Zurita stele.

4.3 Lithic artefacts : a solutrean leafpoint

The solutrean leafpoint from La Garma, Cantabria is broken into three parts, each measuring about 15 x 35 mm (fig. 8). The artefact is very thin and has been used more as a prestige object than a tool. The time for a conventional documentation, e.g. a surface retouch by compression, is very expensive and with at least 2 – 3 h work also very time consuming.

The single parts of the leafpoint have been scanned separately with the MSS-3D with a FOV of 100 mm. The scanning time for each part took about 15 minutes, 8 scans per part were necessary to record even the very thin edges. Therefore, the bifacial retouch is clearly visible on the entire leafpoint.

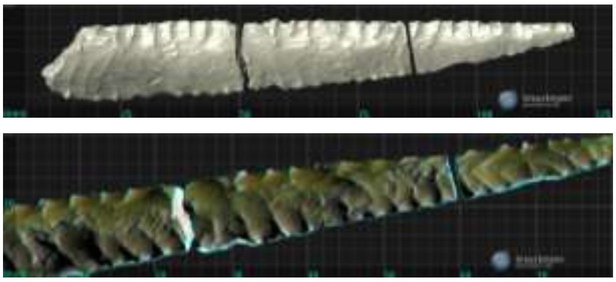

Figure 8: 3D-visualization of the solutrean leafpoint. The orientation of the single parts has been realized using the 3D-shape of the fractures.

4.4 Magdalenian mobile art

As examples of mobile art, we have scanned two small pieces of bone with fine engraved lines (fig. 9 and fig. 11). To reduce distortions caused by the semi-transparency of the bone material, the scans have been done using the MSS-3D scanner with a blue wavelength. The size of the first piece only measured about 20 x 35 mm, allowing us to digitize it with only one scan within one second at highest resolution (FOV of 50 mm). The second piece, an ibex figurine with a size of about 15 x 80 mm has been digitized with two scans within a minute.

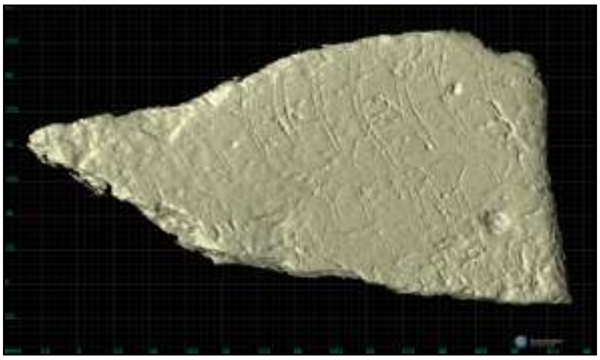

Figure 9: 3D-model of magdalenian mobile art, fine engraved lines on bone.

All the fine engravings are clearly visible in the 3D-models (see fig. 10). The virtual representation also allows to simulate different kinds of illuminations by simply varying the light settings and rendering parameters. By calculating and visualizing the curvatures of the 3D-model, a visualization of the characteristic features of the artefact can be easily generated semi-automatically (see fig. 12).

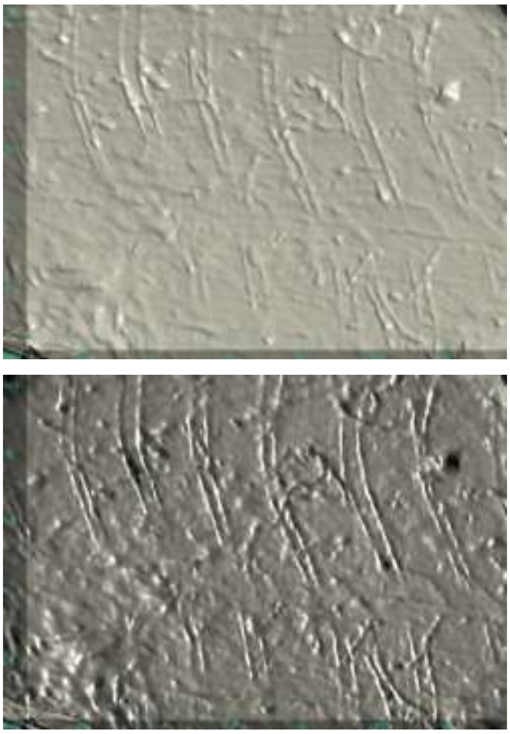

Figure 10: 3D-visualisations of the same object area with different light settings and rendering parameters.

Figure 11: 3D-model of ibex figurine, magdalenian mobile art, engraved lines on bone.

Figure 12: Visualization of characteristic object features based on a curvature plot.

5 Conclusion

3D surface scanning of palaeolithic objects has the potential to substitute drawings as medium for scientific information transfer. Polygon meshes are of high scientific value because they allow an objective record of the object as well as their digital measurement, e.g. distances, angles, areas, volumes etc. (see fig. 13). Once recorded, the digital data file can be transferred via internet and allows direct access to objects. Prehistoric archaeology will have to adapt to this new recording methodology and in the future will require data bases like NESPOS (www.nespos.org) which allow world wide access.

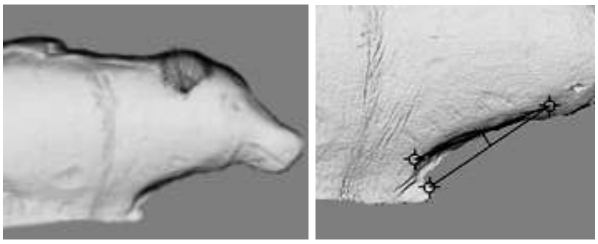

Figure 13: Digital measuring in 3D-meshes.

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