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High Resolution Documentation and Evaluation of Decorated Wall Stones with Optical 3D Measurement Techniques Taking the Megalithic Gallery-Grave at Züschen / Lohne, Germany as an Example

Abstract: A method for quantitative high resolution 3D documentation and investigation of surface structures is presented for which two closely related techniques have been combined: photogrammetry and optical profilometry (fringe projection technique). While the latter is particularly suitable for achieving large quantities of 3D data from limited areas photogrammetry allows a very precise measurement of single points in a wide field. By integrating these methods large surfaces decorated with rock art can be acquired with high resolution. For further evaluation range images are computed which render 3D data as a virtual image where each pixel represents a height value. The example of the gallery-grave at Züschen / Lohne in Hesse, Germany, demonstrates the capabilities of the method.

Introduction

Although the surface of a stone provides a most durable basis for inscriptions or ornament it may degrade within a few decades when exposed unprotected to environmental influences. A typical example is the gallery-grave at Züschen / Lohne in Hesse, Germany (Boehlau / zu Gilsa 1898) *(Fig. 1)*. It has become famous for its megalithic art showing bovines and cart-like signs. Excavated in 1894, it has since then been exposed to damage, by environmental and human influences. In order to conserve this cultural heritage, therefore, comprehensive documentation is an important task. In addition to conventional techniques like drawings and photos optical 3D coordinate acquisition can provide a valuable tool for this task which besides pure documentation may yield new insights on its subject.

A proven method for high resolution 3D acquisition of surface structures is optical profilometry (fringe projection technique) (Dirksen 2000). However it only allows the investigation of limited areas (< 1 m^2). Photogrammetry on the other hand allows the very precise measurement of single points in a wide field (Atkinson 1998). In the measurement system presented here, these techniques are applied in such a way that with photogrammetry the 3D coordinates of a grid of control points are measured (e.g. on several square meters) which are then used as an orientation frame for detailed measurements with the profilometric system. As a result a high resolution (lateral < 0.5 mm, axial < 0.2 mm) 3D model of the surface is obtained which consists of up to 15 million data points.

In contrast to photos or drawings, these measurements not only provide documentation of the images but also yield quantitative data which may be subject to further processing and evaluation.

For further evaluation range images can be computed by projecting the 3D data into a virtual image

Fig. 1. The gallery-grave at Züschen / Lohne in Hesse, Germany (Dirksen 2004).

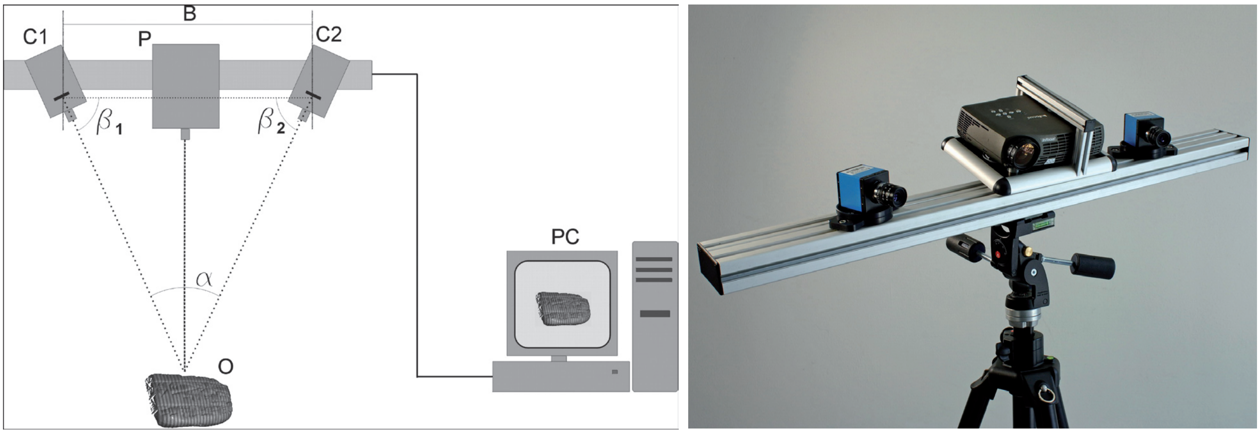

Fig. 2. Left: sketch of the setup for optical profilometry consisting of two video cameras (C1, C2), a video projector (P) and a control computer (PC). Right: The actual setup used during the measurements at Züschen.

Fig. 3. a) The measurement system in front of a wall stone with illuminated measurement field. b) The port-hole slab with attached control points.

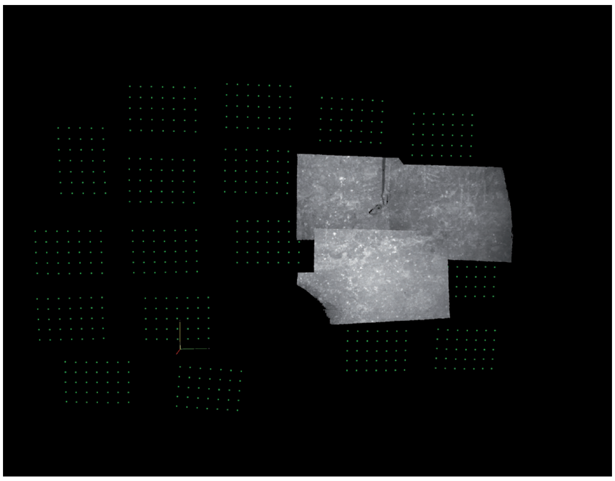

Fig. 4. 3D coordinates of control points (acquired with photogrammetry) together with inserted (registered) high density data obtained with profilometry.

where each pixel represents a height value. Techniques for evaluation of such images are presented together with sample measurements which have been carried out on decorated stones from the gallery grave in Züschen/Lohne.

Methods

What follows is a short introduction to the methods developed at the Laboratory of Biophysics at Münster University. Using optical 3D coordinate measurement techniques, a method has been developed to create a digital three-dimensional documentation of the wall-stone-surfaces and their decoration.

For the 3D acquisition of the surface structures, two closely related methods have been applied: photogrammetry and optical profilometry (fringe projection technique). Both techniques are based on stereo photography, i.e. the object is either recorded with two cameras in parallel (profilometry) or two times in sequence with a single camera

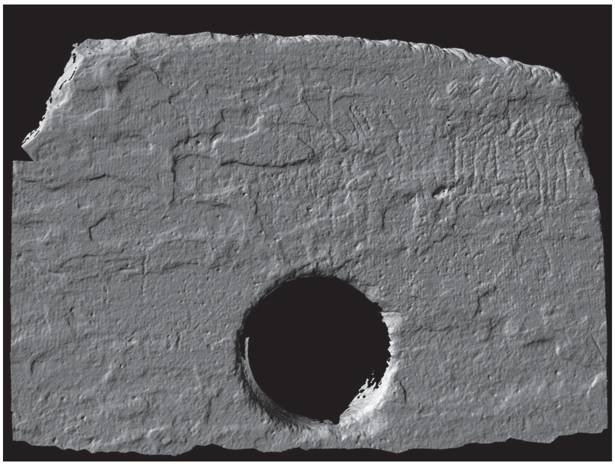

Fig. 5. Image rendered from 3D model of the port-hole slab t.

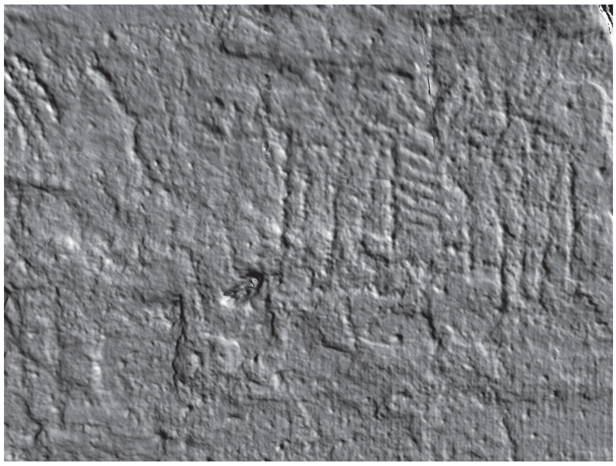

Fig. 6. Detail of the upper right corner of the slab in Fig. 5.

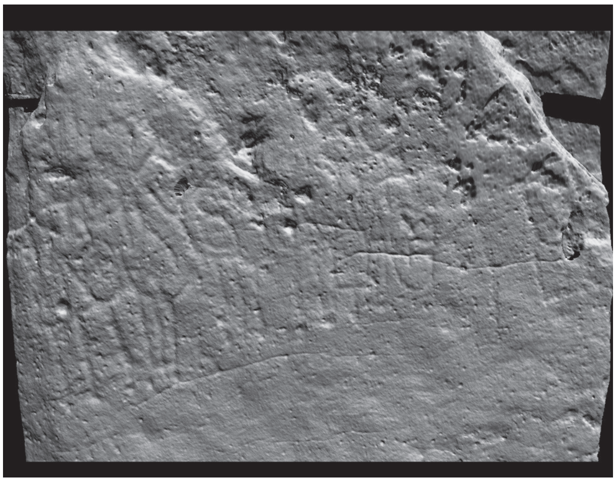

Fig. 7. Image rendered from 3D model of wall stone b2 with "Eye-goddess".

(photogrammetry) from different viewpoints. The position of a particular object point then is determined by triangulation after identifying it in the two images (Atkinson 1998). In the case of photogrammetry this identification is done manually, while for profilometry this process is automated by image processing techniques based on a sequence of fringe patterns projected onto the object *(Fig. 2)*.

In the current case the surface of each stone was divided into approx. 20 sections which were subsequently scanned with the profilometric system *(Fig. 3a, b)*. The spatial position of each section had been determined in advance via attached control plates *(Fig. 3b)* which had been measured with photogrammetry in such a way that during post processing all sections could be assembled *(Fig. 4)* resulting in a complete 3D reconstruction of the surface consisting of circa 20 million data points with a resolution of better than 0.5 mm.

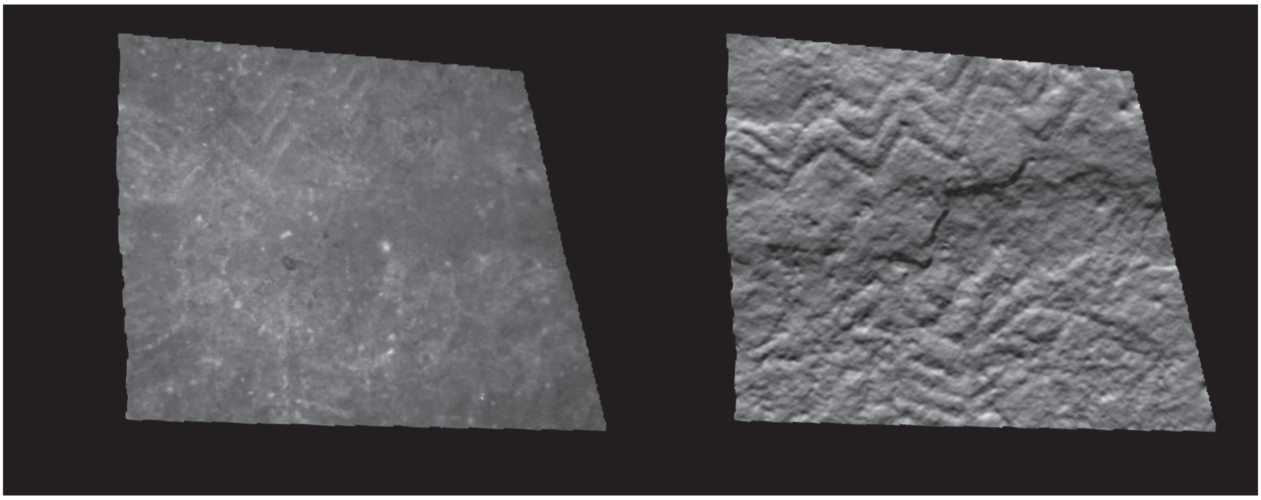

Fig. 8. Surface detail with original shading (left) and surface geometry only, illuminated with a virtual light source (right).

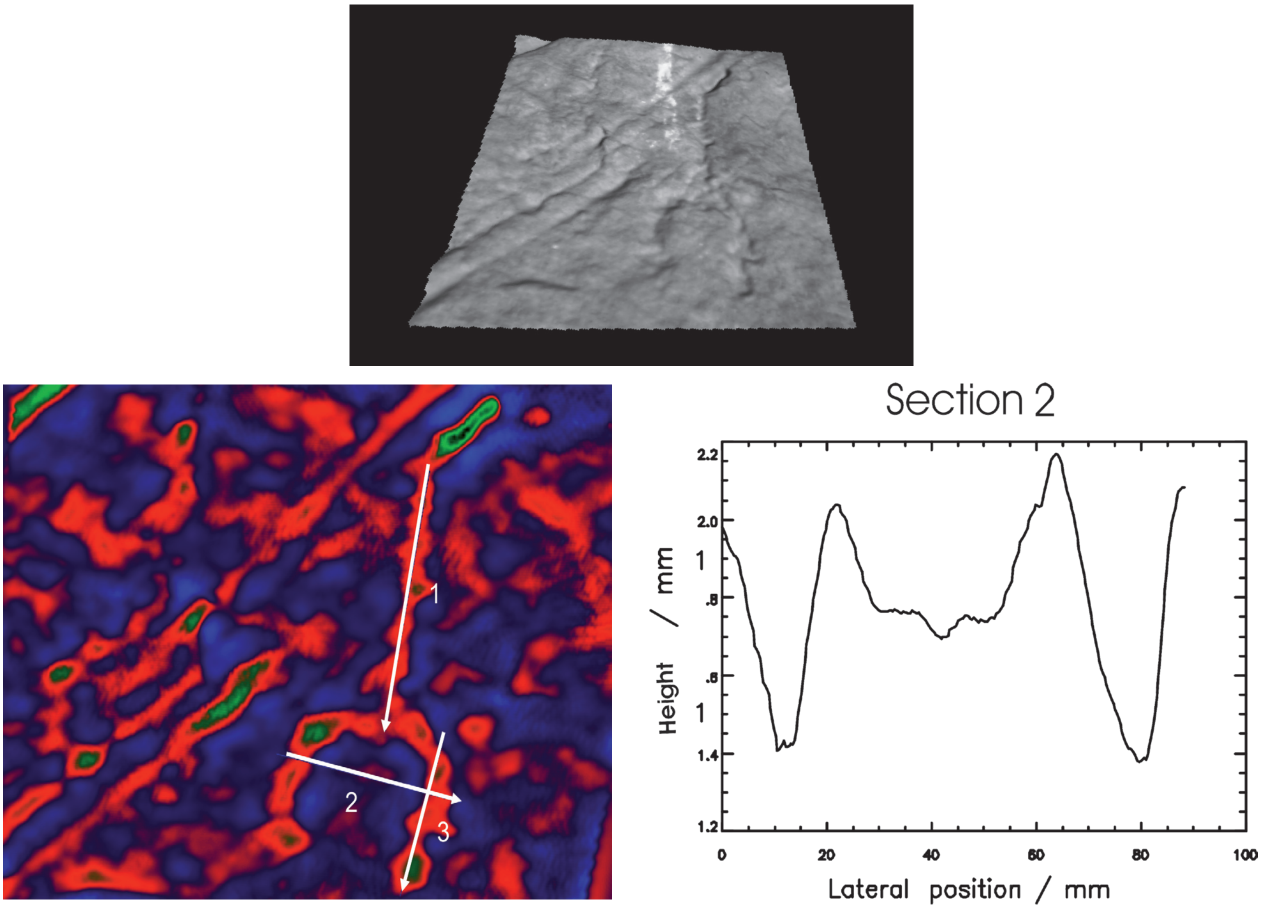

Fig. 9. 3D model of surface detail (top) with false color range image (left) and height section (right).

Results

By way of example the virtual reconstructions of two wall stones are presented. In *Fig. 5 and 6* the port-hole slab is shown. It has to be pointed out that the 3D model consists of quantitative data which can be subjected to further measurements and evaluation.

A basic enhancement of perceptibility is usually obtained by omitting the original colours and thus emphasizing the surface geometry. Rendering the model with various illumination angles can further enhance the visibility of details as such virtual light sources have far more accentuated illumination properties compared to natural light *(Fig. 8)*.

A tool that turned out to be particularly useful for further processing is the calculation of range images. For this purpose a selected sub-set of the 3D data is re-projected into an image. However, the resulting image points are handled in such a way that each pixel represents a height value with respect to a given plane (e.g. the mean surface of the wall-stone). This representation of the 3D data has the advantage that range information can be visualised in false colour *(Fig. 9)* and e.g. sections can easily be calculated.

Acknowledgements

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References

ATKINSON 1996

K. B. ATKINSON, Close Range Photogrammetry (Caithness 1996).

BOEHLAU / ZU GILSA 1898

J. BOEHLAU / F. VON GILSA ZU GILSA, Neolithische Denkmäler aus Hessen. Zeitschrift des Vereins für hessische Geschichte und Landeskunde. Neue Folge, Supplementheft 12 (1898).

DIRKSEN ET AL. 2000

D. DIRKSEN / K. FREITAG / Z. BÖRÖCZ / C. THOMAS / K. RUFFING / P. FUNKE / G. VON BALLY, Dreidimensionale optische Vermessung von Inschriftenträgern für die digitale Analyse und Dokumentation. In: M. HAINZMANN / C. SCHÄFER (EDS.), Computer und Antike, (St. Katarin 2000) 66-81.

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