The 11th International Symposium on Virtual Reality, Archaeology and Cultural Heritage VAST (2010)
A. Artusi, M. Joly-Parvex, G. Lucet, A. Ribes, and D. Pitzalis (Editors)

Rollouts of Fine Ware Pottery using High Resolution 3D Meshes

S. Bechtold[1] and S. Krömker[1] and H. Mara[1] and B. Kratzmüller[2]

[1]Interdisciplinary Center for Scientific Computing, Heidelberg University - Im Neuenheimer Feld 368, 69120 Heidelberg, Germany
[2]Collection of Antiquities, Vienna Museum of Art History - Burgring 10, 1010 Vienna, Austria

Abstract

A common part of the documentation of archaeological finds is the drawing of so-called rollouts. *Rollouts provide a complete and continuous depiction of graphical elements on the surface of rotation-symmetric objects and are especially useful for the iconographic interpretation of figurative vase painting.*

In the past, rollouts were created either by manual drawing or photographically. We propose a new method to generate rollouts in which the tedious process of manual drawing or the disadvantage of having to decide on a specific projection in advance of any photographical process is replaced by the acquisition of a digital coloured surface model using a structured-light 3D scanner. This model is then used to generate high-quality rollouts with arbitrary projection parameters.

To handle curved vessel profiles, we divide the vessel's surface into multiple segments. Each segment is then approximated with a frustum which serves as a developable auxiliary surface. In the rollout generation process, the vessel's surface is projected onto a frustum's mantle, which is then developed into the image plane. The shape of each frustum is selected in such a way that projection distortions are minimized, but interrelated graphical features like figural friezes are still unrolled in one piece. To control distortion effects in rollouts of non-developable surfaces, we investigated the use of cartographic methods.

A first implementation of our method generates true-to-scale rollouts from meshes provided as PLY files and writes them to a raster image file. Our program uses off-screen OpenGL in combination with tiled rendering *to generate high-resolution images which are suited for professional printing. Exemplary results from the Austrian* Corpus Vasorum Antiquorum *(CVA) project of the* Kunsthistorisches Museum Wien *(KHM - Museum of Art History in Vienna) and the* Universalmuseum Joanneum Graz *(UMJ) are shown.*

Categories and Subject Descriptors (according to ACM CCS): I.3.3 [Computer Graphics]: Picture/Image Generation—I.3.7 [Computer Graphics]: Three-dimensional Graphics and Realism—I.3.7 [Computer Graphics]: Color, Shading, Shadowing, and Texture—J.5 [Arts and Humanities]: Fine Arts—

1. Introduction

A common part of the documentation of archaeological finds is the drawing of so-called *rollouts*. A rollout is a special illustration of an approximately rotation-symmetric object like, for example, a ceramic vessel or a cylinder seal. Rollouts show the surface of an object developed into the image plane and thus provide a complete and continuous depiction of graphical elements on it (figure 1, 2). Since those do often extend around the whole outside of an object, they can never be seen in their full extent when looking at the physical object itself or at perspective images like (conventional) photographs. Due to this nature, rollouts are highly useful as groundwork for further investigations like the iconographic interpretation of figurative vase painting [OTV93].

In order to allow an easier understanding of the whole scene of, for example, an Attic vase-painting, the individual figures are often arranged side by side on panels (colorized copper engravings or colour paintings) since the 18th century (e.g. the publications of the collections of *Sir William Hamilton*). At the beginning of the 19th century, the *Viennese Biedermeier* painter *Peter Fendi* unrolled the figural friezes of the vases of the so-called *Kaiserliches*

DOI: 10.2312/VAST/VAST10/079-086

Figure 1: *A manually drawn rollout [FRH24].*

und Königliches Münz- und Antikenkabinett in Vienna as *gouaches* [BW97]. Besides mere manual free-hand drawings, tracings were produced (e.g. by *Karl Reichhold* in Munich at the beginning of the 20th century), a technique which was taken over also by *John D. Beazley*, one of the important specialists in the research of Attic figured vase-painting [vB83]. A clear disadvantage of all these techniques is that they require frequent direct contact with the vase surface.

Images on cylindrical vase bodies can also be rolled-out by using photographic techniques. The photos of former so-called *cyclographs* [Nob88] and today's *rollout photography*, a type of peripheral photography, afford a contact-free projection of the images and present a planar representation of the object's characteristics. However, all photographic techniques share the disadvantage of having to decide on a specific projection in advance of any photographical process. This paper describes a new method to generate rollouts, based on digital coloured surface models which can be acquired using a structured-light 3D scanner equipped with a color camera [KMS06].

2. Frustum-based rollouts

An important quality criterion for rollouts is that the depicted surface is projected onto the image plane with as little distortion as possible. Here we run into the problem that surfaces which are curved in more than one direction, as they are common in the shapes of many ceramic vessels, cannot be developed into the plane without inevitable distortions. Mathematicians call such surfaces *non-developable*.

Our approach to solve this problem is to divide the object's surface into a number of separate sections (figure 3). Each section is then approximated with a frustum which serves as a developable auxiliary surface. In the rollout generation process, the vessel's surface is projected onto a frustum's mantle, which is then developed into the image plane. This is essentially the same strategy that is used by artists for manual drawing of rollouts.

We found that for the vessels which we used to test our method, about five to seven frustums are sufficient to keep projection distortions at an acceptable level (figure 3). However, the cost of this strategy is that the rollout is split up into several separate images which do not fit together at their borders because of their different projection parameters. As a consequence, the practicability of this strategy depends not only on the object's geometry, but also on its painting and on the intended purpose of the rollout.

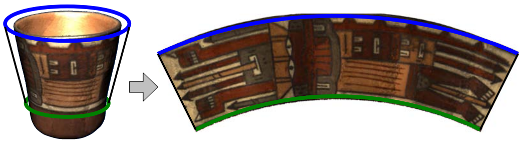


Figure 2: *Conical-Frustum-based rollout of a Nasca vessel (museum copy) [Mar09].*

Figure 3: *A vessel's shape can be approximated with several frustums which are rolled out separately (KHM Inv.-No. 3602).*

2.1. Requirements regarding an object's geometry and painting

An obvious requirement for the effective use of section-wise unrolling is that the object's shape can be approximated with frustums or cylinders with sufficient accuracy. In principle, this is fulfilled by each body which is approximately rotation-symmetric, as long as we do not make any constraints regarding the maximal number of frustums to be used. Nevertheless, fragmenting the surface into dozens of separate images is not appropriate in most cases, since this would nullify the advantage of rollouts over perspective views.

This leads to further requirements regarding the object's painting: The sectioning should be selected in such a way that each individual graphical element is located entirely within a single section. The same applies to groups of interrelated graphical elements which form some sort of semantic unit like, for example, the characters of a figurative scene. So in turn, this requirement implies further limitations to the number of possibilities for the selection of a section.

2.2. The optimal Sectioning

In the case that an object fulfills both of the requirements discussed above, it is up to the artist to select a reasonable sectioning. Sometimes, there is no distinct "best" solution, since the decision may not only depend on quantifiable values, but also on individual demands and conceptions. Basically, the user has to decide the following questions:

- Where is it acceptable to split the image in favor of reduced distortion?
- Where is the continuity of the rendering of higher priority than the minimization of distortions?

3. Complementary strategies

While section-wise frustum-based unrolling can be applied to a large number of objects with very good results, there are still situations where this strategy fails. An example for such a case is a vessel where a broad frieze of painting stretches across a strongly curved section of the vessel's profile (figure 4). In the following subsections, we present complementary approaches which might be useful in such cases.

Figure 4: *A vessel which is unsuited for rollouts based on conical frustums (KHM Inv.-No. 3600). The vertical curvature of the surface area which is covered by the figural frieze makes it impossible to unroll the frieze without noticable distortion.*

3.1. Inspiration from cartography

An almost self-evident idea when dealing with planar projections of non-developable surfaces is to take a look at methods used in cartography, since rollouts and world maps share many similarities. The only real difference - albeit a critical one - is that for the task of drawing world maps, the shape of the Earth can normally be assumed as being perfectly spherical, which greatly simplifies the work of cartographers, while ceramic vessels come in many different shapes. Nevertheless, there is a chance that at least a subset of the rich amount of map making knowledge which has grown over the centuries might be useful for our purpose. Some types of ceramic vessels - like, for example - greek *aryballoi* (figure 5) - have almost spherical shapes. Unrolling the surface of such an object with some sort of cartographic map projection produces better results than the frustum-based method (figures 6, 10). While it is impossible to construct a completely distortion-free projection of a spherical surface onto the plane, cartographers have learned how to at least *control* - to a certain degree - the types of distortions which are caused by a specific projection [Hos69]. For example, there are projections which do either preserve angles (*conformal*) or areas (*equal-area*), but none which does both. Other map projections are neither conformal nor equal-area, but instead equilibrate the different types of distortions with the goal of keeping their average visible effect at a minimum. All in all, there are hundreds of map projections with different properties which might be useful for making rollouts of archaeological objects. By taking a look at how cartographic map projections are designed, it is possible to learn how to construct and improve projections with specific distortion-controlling properties for arbitrary curved surfaces as well.

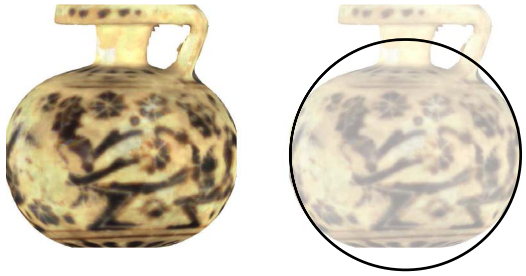
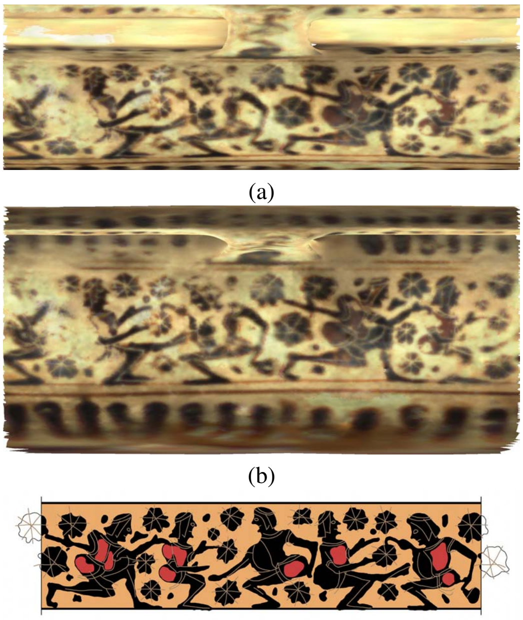


Figure 5: *An* aryballos *(UMJ Inv.-No. 8738). This type of vessel has an almost spherical shape which makes it a good candidate for rollouts with cartographic map projections.*

3.2. Context-aware corrections

Even if it is not possible to find any global projection which produces acceptable results, there is still a very simple yet effective option left, that is *manual distortion correction*. For example, imagine a painted scene with two human figures which is projected onto the plane in such a way that the two figures are heavily compressed in the vertical direction, making them appear unnaturally short and wide. As long as the width of the empty space between the figures does not carry any iconographic meaning, one could easily improve the appearance of this image by reducing the width of the figures. This way, their original proportions could be re-established.



(a)

(b)

(c)

Figure 6: *Comparison between* cylinder projection *(a),* equirectangular projection *(b) and* hand-drawn rollout *of the* aryballos *depicted in figure 5 (UMJ Inv.-No. 8738, hand-drawn rollout by Stephan Karl, Graz).*

4. Data acqusition and representation

As input data, our rollout generation algorithm requires a three-dimensional digital surface model, also called a *mesh*, of the object which is to be unrolled. The most practical method to acquire such a model is to capture the object with a *structured-light 3D scanner* [MTKZ07]. Since the generation of rollouts requires a complete model of the object's whole surface, multiple scans from different directions must be acquired for each vessel. These partial models are then merged (*registered*) and saved in the *Stanford PLY* 3D model file format using an appropriate software package [BR02].

PLY files, as well as many other 3D model file formats, describe the geometry of an object in form of a list of 3D points, so-called *vertices* and a second list of *triangles*, also called *faces*. Each vertex represents a point on the object's surface, while the triangles provide a linearly interpolated description of the surface's shape and position between these points. Each vertex is stored in form of two 3D vectors - one representing its position in space, the other describing its colour in red, green and blue channels. Each triangle is defined by a set of three references to the list of vertices - one for each of the triangle's corners. The process of deciding which vertices are connected to form a triangle is called *triangulation* or *meshing*. It is done automatically using appropriate software algorithms [HK09], [Fab03]. This kind of data structure to describe the surface of a three-dimensional object is called a *face-vertex mesh*. Our rollout generation software reads PLY files and works directly on the face-vertex mesh data structure described above.

5. Geometrical solution

Our process of generating a rollout from a face-vertex-mesh consists of two steps: In the first step, the mesh is transformed from its original shape to the unrolled shape by projecting the coordinates of each vertex onto the image plane. The exact behaviour of this transformation depends on the rollout parameters defined by the user. In the second step, the unrolled mesh is rendered into a raster image.

In this section, we explain the computation of frustum-based rollouts according to the concept described in section 2. It has already been said that this type of rollout is based on the idea of projecting the original surface onto the mantle of a frustum, which is then *developed* into the image plane. We first explain the development of a complete cone and then expand this solution to the development of a conical frustum.

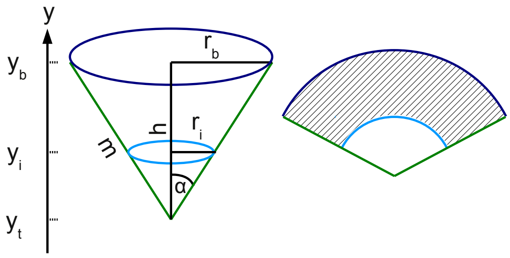


Figure 7: *A frustum is developed into a circular sector.*

5.1. Developing a cone

To describe a cone and its position on the symmetry axis of the mesh which we want to roll out, three variables are required: The vertical position of the cone's base y_b, the base radius r_b and the vertical position of the tip y_t. So, the height h of the cone is

$$h = |y_b - y_t|.$$

Height and base radius are used to calculate α, the half of the cone angle, with

$$\alpha = atan\left(\frac{r_b}{h}\right).$$

Developing the mantle of a cone onto the plane results in a so-called *circular sector* (figure 7), with the height of the cone's mantle m being equal to the radius of the circular sector. This value can be calculated using *Pythagoras' theorem* with

$$m = \sqrt{r_b^2 + h^2}.$$

Furthermore, the circumference of the cone's basis is equal to the arc length of the circular sector. We call this length u. The total circumference of the circle in the plane is called u':

$$\begin{aligned} u &= 2 \cdot \pi \cdot r_b \\ u' &= 2 \cdot \pi \cdot m \end{aligned}$$

The scaling factor for the transformation of the vertex's longitudinal angle φ from its original position on the cone's surface (in cylindrical coordinates) to its position on the circle (in polar coordinates) is equal to the ratio between the circumference of the cone's base and the circumference of the circle or between the cone's base radius and mantle height, respectively. According to this, the first component of the rollout transformation is

$$\varphi' = \varphi \cdot \frac{u}{u'} = \varphi \cdot \frac{r_b}{m}.$$

Instead of r_b/m, we can also write $sin(\alpha)$: The cone's tip, the centre of the cone's basis and an arbitrary point on the edge of the cone's basis form a right-angled triangle, with the mantle's height m being its hypotenuse and the radius of the base r_b being the opposite leg of the angle α.

The second component of the transformation is constructed in a similar fashion. Here too, the scale factor is a ratio: In this case, it is the ratio between the cone's height h and the height of the mantle m, since the distance of a point from the cone's tip decides about the distance of the projected point from the center of the circle. However, this value cannot be used directly, since the radius of the circle is equal to the height of the cone's mantle, which is larger than the height of the cone. So, the formula to translate the height h_p of a point inside the cone volume to its radius h'_p on the circle is

$$h'_p = |y_t - h_p| \cdot \frac{m}{h}.$$

In analogy to the corresponding statement for the first component of the mapping, we notice that we can write m/h as $1/cos(\alpha)$. So, the complete formula to calculate the rollout of a cone mantle into a circular sector is

$$(\varphi', h'_p) = f(\varphi, h_p) := \left(\varphi \cdot sin(\alpha), \frac{|y_t - h_p|}{cos(\alpha)} \right).$$

5.2. Developing a frustum

To define and develop a frustum instead of a complete cone, the method explained above needs to be slightly modified. In comparison to a complete cone, the description of a frustum requires one additional variable - the radius of the frustum's other flat end. The vertical position of the frustum's *lower* end is now called y_1, its radius is called r_1. The values for the *upper* end are now called y_2 and r_2. We note that we do *not* define which end is the one with the larger, respectively smaller radius. In our implementation of the algorithm, the special case $r_1 = r_2$, which describes a cylinder, is also handled correctly.

Regarding the actual rendering, the only difference between the rollouts of a complete cone and a frustum is that all triangles of the mesh which are located between the narrow end of the frustum and its imaginary/projected tip are not drawn. The actual transformation is identical to the formula which has already been explained above. To use this formula, we need to know α, the half of the cone angle, and y_t, the position of the cone's tip. We calculate α with

$$\alpha = atan\left(\frac{|r_2 - r_1|}{|y_2 - y_1|} \right).$$

The height of the cone's tip is not directly given, it must be calculated using the variables which describe the frustum. The height h of the full cone is

$$h = \frac{max(r_1, r_2)}{tan(\alpha)}.$$

Using this value, we get y_t with the distinction of two cases: If $r_1 > r_2$, then $y_t = y_1 + h$, otherwise $y_t = y_2 - h$.

5.3. Solving the depth order problem

For the purpose of rollout generation, we are only interested in an object's outer appearance. In the case of a ceramic vessel, a mesh which does only represent the outside of the vessel's wall is not only sufficient, but even desirable, since the reduced complexity of such a model simplifies and accelerates the rollout generation process. However, 3D models of archaeological objects are often produced to be suitable for as many scientific purposes as possible. Thus, they usually represent the object as completely as possible, which, in the case of ceramic vessels, includes the inside surface as well. For example, this is required to use the mesh for profile drawings or volume calculation [SKM09].

If we want to draw rollouts of vessel meshes which contain the inside of the wall, we must find a way to make sure that only the outside is drawn. This can be achieved by taking into account the the object's geometry during the drawing process: We need to make sure that along each line of sight, the pixel which represents the point of the surface which is closest to the viewer is drawn on top of all others. In other words, the rollout transformation must fully preserve the mesh's spatial information, even though the final product, the rollout, is clearly a two-dimensional image.

This is achieved in the following way: Before the rollout transformation is applied to a vertex, its distance or *radius* from the rotational axis of the auxiliary frustum is saved to a temporary variable. After the x- and y-position of the transformed vertex on the rollout plane is computed, the saved distance value is added as an offset to the transformed vertex's z-coordinate, which is otherwise zero for all transformed vertices. Doing so, the radial distances of the vertices relative to each other are transferred from the original to the unrolled mesh. The result is a three-dimensional rollout which allows to distinguish triangles that belong to the outside of the vessel's wall from those that belong to the inside (figure 8). This enables us to draw rollouts which do only show those parts of the mesh's surface that are visible from the outside.

Figure 8: *Oblique view of an unrolled mesh (KHM Inv.-No. 3618). The thickness of the vessel's wall is visible at the border.*

6. Implementation

As a proof of concept as well as for early practical use, we have implemented a command line tool in C++ which uses the method described in this paper to generate rollouts of meshes provided in the Stanford PLY file format (ASCII version). This section introduces the core technologies and primary features of our program and explains why and how they were implemented.

The program reads a given PLY file and stores the mesh data in a simple structure of linked *Vertex* and *Triangle* objects. It calculates and renders the rollout by iterating through the list of triangles, transforming and drawing one triangle after the other until the end of the list is reached.

6.1. Hardware-independent OpenGL rendering with Offscreen Mesa

To render the rollout, our program uses the *Offscreen Mesa* (*OSMesa*) library. OSMesa is a special implementation of the *OpenGL* graphics API which, in contrast to more commonly used implementations, does not make use of graphics hardware acceleration and does not send its output to the computer display. It is a CPU-driven *offscreen renderer*. As the rendering target, OSMesa uses a buffer in the computer's main memory. After the rendering process is finished, our program reads the image from this buffer and writes it to an image file for further processing. For this task, we use the *FreeImage* library, which supports reading and writing of a large number of image file formats like TIF, JPEG, PNG or PSD [PK03].

6.2. Generating large images with tiled rendering

One disadvantage of OpenGL for the production of images suited for high-quality printing is that the maximal size of the frame buffer is typically limited to a few thousand pixels in width and height. The actual size depends on the used OpenGL implementation and, if the implementation is hardware-accelerated, on the used graphics card model. In Offscreen Mesa, the maximal frame buffer size is 4096 × 4096 pixels.

To work around this limitation, we use a technique known as *tiled rendering*. The idea behind tiled rendering is that instead of drawing the whole image at once, it is split up into several smaller *tiles*, each one not larger than the maximal frame buffer dimensions. The image is then drawn tile by tile, with each tile being copied from the OpenGL frame buffer to a secondary image buffer before its instance in the OpenGL frame buffer is overwritten by the rendering of the next tile. This secondary buffer is allocated independent of OpenGL and large enough to hold the whole image, which can now be larger than the OpenGL frame buffer. This technique allows us to generate images of almost arbitrary size, only limited by the amount of available memory.

6.3. User-definable prime meridian

In cartography, the *prime meridian* of a map is the angle of longitude which a map is centered around. The same concept can be applied to rollouts. By default, the prime meridian of a rollout generated by our program is the positive direction of the *x*-axis in the original mesh's Cartesian coordinate system. However, our program allows the user to change this. This feature can be used to move a specific area of interest to the center of the rollout, or simply to establish a symmetry of some sort to make the rollout look more aesthetic (figure 9).

Figure 9: *A figural frieze from a crater, unrolled with different prime meridians (KHM Inv.-No. 3618).*

7. Results

To test our method, we used 3D scans of ceramic vessels from the collections of antiquities of the *Kunsthistorisches Museum Wien* and the *Universalmuseum Joanneum Graz*. The vessels were scanned using a high precision structured-light 3D scanner (*Breuckmann smartSCAN-3D-HE*) [SM92]. Figure 10 shows another example of the equirectangular map projection applied to a vessel from the KHM. Two results of the frustum-based method are shown in the figures 11, 12. These tests prove that the frustum-based rollout algorithm produces results which are very similar to typical manual drawings.

Within the latest CVA project, the rollouts will be taken as basis for the documentation of so-called *preparatory drawings* - painted or incised lines which were used to sketch the figures on the vases before painting them.


(a)


(b)

Figure 10: *Comparison between cylinder projection (a) and equirectangular map projection (b) of the figural frieze of the vessel depicted in figure 4 (KHM Inv.-No. 3600).*

8. Outlook

Currently, our rollout generation software is controlled entirely with command line arguments, which is cumbersome not only for users with a non-technical background. The implementation of a modern, intuitive graphical user interface (*GUI*) would greatly increase the program's value for everyday use. Such a GUI could provide a three-dimensional view of the mesh and allow the user to rotate and zoom this view.

Acknowledgements

We would like to thank *Dr. Alfred Bernhard-Walcher*, director of the collection of antiquities of the *Kunsthistorisches Museum* (KHM), Vienna, as well as *Stephan Karl* from the *Universalmuseum Joanneum* (UMJ), Graz, for kindly authorizing us to present images of items from the respective collections.

The 3D scanner used for this work was provided by the *Heidelberg Graduate School of Mathematical and Computational Methods for the Sciences* (HGS MathComp). This work is part of the *IWR Pioneering Projects* (IPP) and partially funded by the HGS MathComp – DFG Graduate School 220.

References

[BR02] Bernardini F., Rushmeier H. E.: The 3D model acquisition pipeline. *Comput. Graph. Forum 21*, 2 (2002), 149–172. 4

[BW97] Bernhard-Walcher A.: Griechische Vasen und ihre Abbilder. In *Antike Welten: Meisterwerke griechischer Malerei aus dem Kunsthistorischen Museum Wien* (Ostfildern-Ruit, Germany, 1997), Grewenig M. M., (Ed.), Hatje Cantz Verlag, pp. 146–147. 2

[Fab03] Fabio R.: From point cloud to surface: The modeling and visualization problem. In *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* (2003), vol. XXXIV-5/W10. 4

[FRH24] Furtwängler A., Reichhold K., Huber A.: *Griechische Vasenmalerei*. Bruckmann, München, 1924. 2

[HK09] Hoppe C., Krömker S.: Adaptive meshing and detail-reduction of 3D-point clouds from laser scans. In *International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences* (2009), vol. XXXVIII-5/W1. 4

[Hos69] Hoschek J.: *Mathematische Grundlagen der Kartographie*. BI-Hochschultaschenbücher ; 443/443a. Bibliogr. Inst., 1969. 3

[KMS06] Kampel M., Mara H., Sablatnig R.: Automated Investigation of Archeological Vessels. In *Proc. of 14th European Signal Processing Conference (EUSIPCO)* (Florence, Italy, 2006), pp. CD–ROM. 2

[Mar09] Mara H.: *New Technologies for Archaeology - Multidisciplinary Investigations in Palpa and Nasca, Peru*, 1 ed. No. XVII in Natural Science in Archaeology. Springer, 2009, ch. Pottery plotted by Laser - 3D-Acquisition for Documentation and Analysis of Symmetry of Ancient Ceramics, Part V – Geomatics, pp. 379–408. 2

[MTKZ07] Mara H., Trinkl E., Kammerer P., Zolda E.: 3D-Acquisition of Attic Red-Figured Vessels and Multi-Spectral Readings of White Primed Lekythoi of the Kunsthistorisches Museum Vienna for the new CVA Volume. In *Proc. of 9th European Meeting on Ancient Ceramics âĂŞ "Vessels: Inside and Outside" (EMAC)* (Budapest, Hungary, 2007). 4

[Nob88] Noble J. V.: *The Techniques of Painted Attic Pottery*. Thames and Hudson, London, 1988. 2

[OTV93] Orton C., Tyers P., Vince A.: *Pottery in Archaeology*. Cambridge University Press, Cambridge, 1993. 1

[PK03] Polak M., Kurka G.: pOSRT - A Parallel OffScreen Rendering Tool. In *CISST* (2003), Arabnia H. R., Mun Y., (Eds.), CSREA Press, pp. 399–404. 6

[SKM09] Stephan Karl D. J., Mara H.: Insights in manufacturing techniques of ancient pottery. In *Proc. 10th European Meeting on Ancient Ceramics (EMAC'09) "From Crafts to Science"* (London, United Kingdom, 2009). 5

[SM92] Sablatnig R., Menard C.: Stereo and Structured Light as Acquisition Methods in the Field of Archaeology. In *Mustererkennung '92, 14. DAGM-Symposium Dresden* (1992), Fuchs S., Hoffmann R., (Eds.), Springer, pp. 398–404. 6

[vB83] von Bothmer D.: The execution of the drawings. In *The Berlin Painter* (Oxford, 1983), Kurtz D. C., Beazley J., (Eds.), Clarendon Press, pp. pp. 6–8. 2

Figure 11: *Rollout of both figural friezes of the vessel KHM Inv.-No. 3618*

Figure 12: *Rollout of the figural frieze of the* kylix *UMJ Inv.-No. 8648*