Rollout Archaeological Photography for the Graphic Documentation of Cultural Heritage

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Peripheral or rollout photography is a non-destructive technique designed to “unroll” the surface of an object in order to represent it on a flat surface and to obtain a more comprehensive and continuous view of the object’s decorative motifs. This technique is especially useful when applied to cylindrical objects. Recently, this process has been simplified with the advent of digital photography. Today, it is not only possible to use conventional cameras, but also to work with filters and digital treatments that go beyond the traditional photo. Digital rollout imagery in archaeology provides the opportunity to visualize decoration completely, thereby providing detailed analysis and documentation by allowing for the integration of the iconographic content of three-dimensional structures with decorations on all sides, shown by the same two-dimensional aesthetic narration. This work will present the methodology used to obtain high-resolution rollout images considering all of the technical aspects from the photo shoot through to digital processing. In addition to highlighting issues that have not always been accurately addressed, such as color calibration, we will show our own development techniques to merge and "unroll" the images. Finally, we will explain how the application of specific filters (such as DStretch) can reveal aspects of decoration that are not clearly visible in the conventional image, improving its documentation and thereby providing a thorough reading for the study of these collections. This process will be applied to the so-called “The Warriors´ Cup” of Archena, a large Iberian *kalathos* from the Hellenistic period decorated in ochre tones, which is currently on display at the National Archaeological Museum of Madrid.

Key words:
Digital photography, Graphic documentation, Rollout photography.

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INTRODUCTION

Archaeological photography is intended to provide accurate and reliable graphic documentation of archaeological objects, considering that the images must preserve all of their dimensional and chromatic properties. There are several techniques to enhance and improve the final results in order to give users a better understanding of the archaeological object, and to graphically document our cultural heritage. One of these techniques is called rollout photography.

Peripheral or rollout photography is a technique that aims to “unroll” the surface of an object in order to represent it on a flat surface and to obtain a more comprehensive and continuous view of the decorative motifs. The purpose is to obtain a flat view with minimum geometrical distortion of cylindrical vases, jars or similar archaeological objects [Felicísimo 2011] with the consequent advantage of visualizing all of the information contained in the object in a single panoramic photograph.

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Rollout photography was developed in the mid-twentieth century using analogue photography, and was further developed in 1970 when Justin Kerr made a series of hundreds of rollouts of Mayan vessels[1]. This vase database offers information about each vase (such as its type, size, and owner) and makes it possible to visualize both the image of the original object and the rollout image. Historical information can be accessed in [Davidhazy 1986; Kerr 2007].

This process has been simplified using digital photography because it allows working with more filters and digital treatments than traditional photo.

In addition to rollout photography, there are other techniques that make it possible to explore in even greater detail the information contained in the digital image of an archaeological object, for example, by applying specific filters that can reveal aspects of decoration that are not clearly visible in the conventional image.

The aim of this paper is to explain the workflow of two specific techniques applied to archaeological photography: rollout photography, and the application of filters to highlight pigments and to enhance colours. The study case will be a cylindrical Iberian cup decorated with a continuous frieze around the vessel. This cup has been chosen because of its geometric characteristics and its pigments.

MATERIAL

The Warriors' vessel was found in a necropolis in Archena (Murcia, Spain) [García Cano and Page 1990]. This vessel is 41 cm high with a maximum diameter of 36 cm, and has been dated to the third century B.C. It is in the Museo Arqueológico Nacional of Spain (reference 1918/69/1). The frieze around the center of the vessel shows different scenes of warfare: a duel between foot soldiers, a clash between a foot soldier and a cavalryman, and another cavalryman who is riding with his lance to provide support. These episodes are watched by animals, such as a wolf and several wild boars, all of whom are involved and included in this story. A unique element in Iberian iconography found on this vessel is the presence of injured or wounded figures in the bottom part of the frieze: some of them are even shown still pierced by the lance that killed them. The warriors, shown wearing belts, carry different weapons such as the *falcata*, lance, or oblong shields (Fig. 1) [Tortosa and Santos 1997; 1998]. It is thought that the vessel was used as a container for the cremated remains of the deceased. In brief, this large vessel features one of the best known and unique Iberian iconic narratives [Tortosa 2006]. The vessel is currently on display at the National Archaeological Museum of Spain (Reference 1918/69/1).

The importance of this technique for historians not only lies in the fact that it makes it easy to see a continuous image of the pictorial frieze, but also in that despite the deterioration it suffers, it can be preserved for future generations.

As the cup has a cylindrical shape and shows figures in a continuous frieze around the vessel, it is a perfect object to be photographed using the rollout technique [Felicísimo et al. 2017].

The photographs were taken with a Pentax 645Z camera (51 Mpx) with a 120 mm Pentax calibrated lens. The additional material used included NanGuang bicolour LED panels (CRI > 92), a manual turntable, a Manfrotto tripod to prevent camera movement, an external photometer Sekonic L-308S, and an X-Rite card for color calibration. It was not necessary to use a polarizing filter as the vessel has a matt finish.

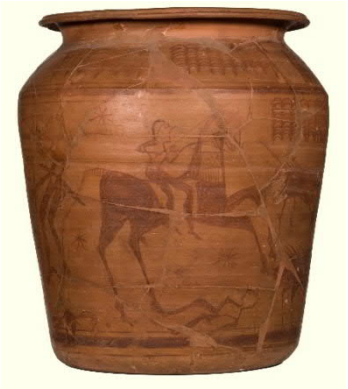

Fig. 1. The Warriors' vessel (National Archaeological Museum of Spain) (Ref. 1918/69/1)

[1] http://www.mayavase.com/

Several software applications were used to complete the rollout process and to apply filters to enhance the pigments and colors:

Adobe Photoshop is a commercial software used for image editing, digital art and graphic design. Adobe Photoshop is used for the basic processing of RAW images into TIFF format. This process includes the importing (Adobe Camera Raw), color balance and calibration processes, and image cropping. A free alternative option is GIMP[2].

The image fusion was carried out using Microsoft ICE[3], a free software that makes it possible to choose different projections of the results. Other options are PTGui[4], Panorama Factory[5], or Hugin[6].

Finally, DStretch is a plugin for the free software programme ImageJ[7] created by Jon Harman. Dstretch includes several image enhancement techniques.

METHODOLOGY

The procedure involves two separate stages; the first consists of creating the rollout photograph, and the second consists of applying specific filters to enhance the decorative motifs.

To create the rollout photograph, the object is placed on a turntable so that it can rotate on its axis. The optical axis of the camera must be horizontal and point to the axis of rotation, in the center of the vessel. A series of overlapped photographs is taken by rotating the table at regular intervals so that each of them picks up the central part of the object and overlaps them with the previous and subsequent shots. Usually, the shots must complete a full rotation around the object. Some complementary technical issues about the image captures are:

- ISO sensitivity was set to the minimum value (100) so as not to add electronic noise. Since the camera is on a tripod, using longer shutter speeds is not a problem.
- The diaphragm value was set to 11. Values f:8 to f:11 are the ones that offer maximum acutance in the images and present the minimum values of distortion and chromatic aberrations (these values must be determined beforehand by means of specific tests). In addition, it guarantees that the depth of field is sufficient for the area of interest of the vessel to be focused.
- The measurement of light has been made by means of an external photometer.
- To reduce trepidation, the shooting mode is in two steps: mirror rise and shooting. The camera is triggered remotely, either by cable (preferred method for us) or with an infrared remote control.
- Images are captured in RAW format (DNG, 14 bits), providing a large amount of radiometric information.
- The distance between the camera and the object should be as small as possible to cover as much of the sensor and achieve the highest possible spatial resolution.

The shots are corrected for colour bias and by transforming the image from RAW to 16-bit TIFF format using Adobe Camera Raw or similar software and a specifically generated color profile from the color chart. In this case, a total of 36 images were taken with a rotation of 10º between each image. The degrees of rotation and the number of shots depend on the vase radius to ensure the minimum distortion value in the central part of the image.

Each photograph is trimmed to the same size using a rectangular frame, maintaining the same height and only conserving the part to be "unrolled" as well as the overlapping areas between consecutive images (Fig 2). It is necessary to trim the images in order to eliminate the areas with higher distortion on the edges of the image. In general, only one third of the photograph is preserved. The stage is performed with image- processing software as GIMP (open source) or Adobe Photoshop (commercial).

[2] GNU Image Manipulation Program, https://www.gimp.org/
[3] Image Composite Edition, https://www.microsoft.com/en-us/research/product/computational-photography-applications/image-composite-editor/
[4] commercial, https://www.ptgui.com/
[5] commercial, http://www.panoramafactory.com/
[6] free and open source http://hugin.sourceforge.net/
[7] https://imagej.nih.gov/ij/ available from http://www.dstretch.com/

Fig. 2. Each photograph is trimmed to the same size using a rectangular frame, maintaining overlapping areas between consecutive images

The next step is to fuse the images into a single image by aligning and merging individual shots supported by overlapping areas. The software automatically searches for tie points, corrects distortion and creates a unique image as the output (Fig. 3).

The final image, with balanced color, contrast and luminosity, can be added to the documentation of the archaeological object. There are complementary techniques that can be used to solve specific problems, such as diffuse lighting or cross polarization, macro photography, or color calibration.

Although the used technique may seem similar to SfM (Structure from Motion), the objective and process are different. SfM aims at the construction of 3D models by photogrammetry from 2D images [Remondino et El-Hakim 2006; Remondino et al. 2014]. Rollout technique aims merging 2D images to generate a global 2D image as a cartographic projection. Both are different in software tools, process, involved statistics and results. In any case, the images taken for SfM process may be useful for rollout if this has been anticipated in the shooting planning.

The second proposed procedure is the application of the DStretch filter (a plugin for the free ImageJ software) originally developed for processing images of prehistoric rock art. DStretch performs a decorrelation stretch on color images [Alley 1996]. Decorrelation stretching is an image processing technique, first used in remote sensing, that enhances the color separation of any image removing the correlation found in RGB image bands and equalizing the variances. The calculation produces a 3x3-transformation matrix that is then applied to the RGB bands colors in the original image to project them on different color axes. The new image enhances the colors and can improve the visual interpretation and make feature discrimination easier but the effectiveness of each transformation is little predictable and all the options must be tested to choose the right one. DStretch supports several own color spaces: YDS, YBR, YBK, LDS, LRE... that are modifications of the conventional YUV or LAB color spaces, and includes the possibility of designing own color spaces [Harman 2015]. Fig. 4 shows the image of the Warriors' vessel and the same image after applying the LDS transformation. LDS is described as a general purpose enhancement that emphasizes the yellow and ochre-colored traces. The result is that decorative motifs are highlighted, and make it possible to see the picture, vessel, or any decorated objet from a new perspective.

RESULTS

All of the operations explained in the methodology section to create rollout photography result in the full image shown in Fig. 3. This image has a slight geometrical distortion resulting from cylindrical vases with all the

information contained in the object in a single panoramic image. The size is 11522 x 3443 pixels and the resolution is approximately 0.1 mm/pixel.

Fig. 3. Final image obtained from the rollout process (11522 x 3443 pixels)

This image can be processed to try to enhance the colors using DStretch (see Methodology). Fig. 4 shows the result of applying the LDS filter to a single image and Fig. 5 shows the result using the rollout image, which seemingly provides more visual information than Fig. 3.

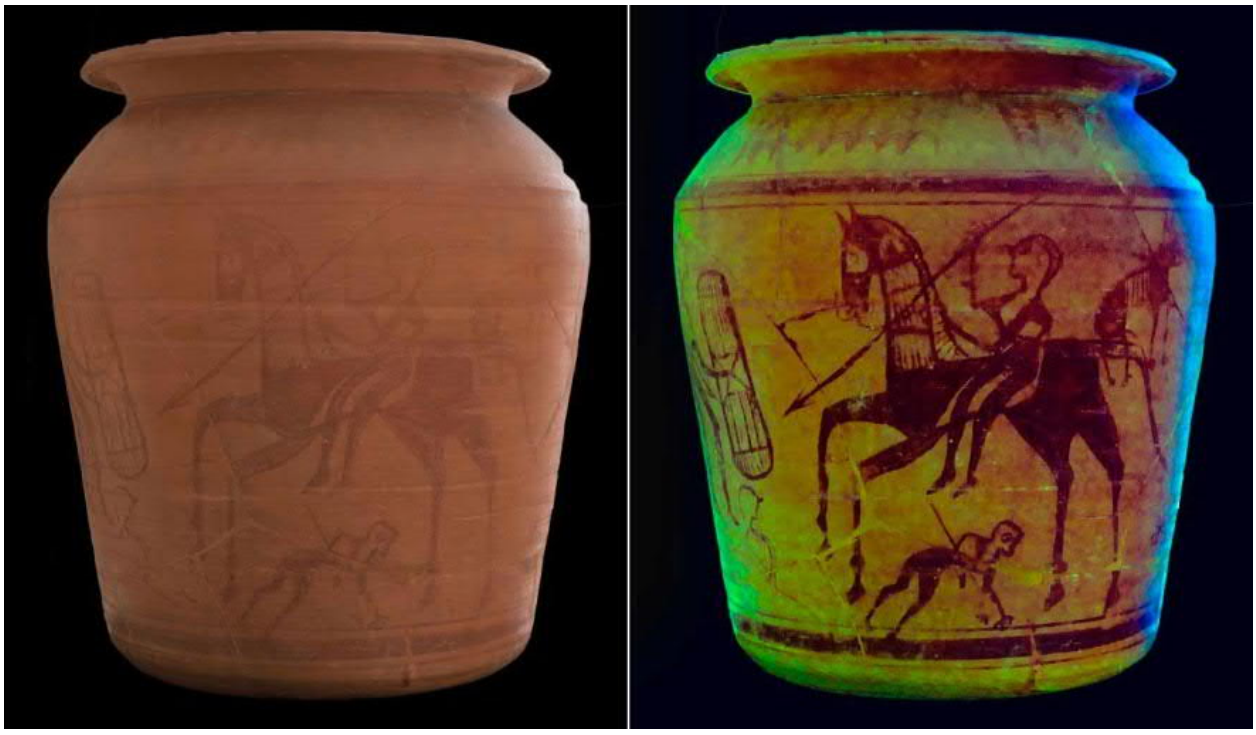

Fig. 4. D-Stretch filter applied to a single image of the Warriors´ vessel

All of the figures are enhanced, and it is easier to analyze the details of the decoration. Finally, a LDS filter has been applied to the images to generate a 3D model by means of Agisoft Metashape. This is a procedure where the original images are replaced by those processed with the model already built, which avoids the need to perform photogrammetric calculations again. The result[8], although not the objective of this work, effectively complements the rollout method and extends the usefulness of DStretch color transformations.

[8] https://skfb.ly/6NuTw and https://skfb.ly/6NuT9

Fig. 5. LDS algorithm of D-Strech applied to the final rollout image

The authors think that the quality of the textures of the 3D models by SfM is worse than the ones got with the rollout method, both in resolution and color fidelity. Rollout can use very large images without needing large computer resources because the underlying process is much simpler than in the case of 3D techniques. Textures from the 3D models typically have a few tens of megabytes while those used for rollout can be much larger. In this example images with 51 Mpx images were used to have a good resolution and the resulting image has a size of 165 Mb. Building a texture of this size using SfM is, in the authors' opinion, unsuitable. Moreover, the "development" of an object from the 3D model to a projected flat image is not a procedure foreseen in SfM programs. With regard to the quality of the color, we have done some analysis on the quality of images or textures from SfM. The results show that the textures do not have good color fidelity, especially the dark tones (i.e. bronze objects). The reason is that the SfM software (we use Agisoft Metashape) does not includes specific color management procedures, as the Adobe Photoshop or other professional photo editors. We are currently working on a procedure for the control and improvement of color in photogrammetric 3D models, one of whose objectives is to locate the critical points where color is distorted and look for an alternative.

CONCLUSIONS

Several photographic techniques are available that make it possible to improve the graphic documentation of the cultural heritage.

Rollout photography is a technique that makes it possible to 'unwrap' the information contained in a cylindrical vase with minimum distortion. The use of appropriate photographic techniques helps to achieve a high-quality final product, both in spatial resolution, color fidelity, and acutance.

The use of digital rollout imagery in archaeology offers the opportunity to completely visualize the decoration of objects, thereby providing detailed analysis and documentation by allowing for the integration of iconographic content of three-dimensional structures with decorations on all sides, shown by the same two-dimensional aesthetic narration

Moreover, the application of specific filters (such as DStretch) can reveal aspects of the decoration that are not clearly visible in conventional images, thereby improving the graphic documentation of cultural heritage.

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