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Portable and low-cost solutions to the imaging of Paleolithic art objects: A comparison of photogrammetry and reflectance transformation imaging

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ABSTRACT

Recent advances in technology have opened up a wide range of new documentary techniques to archaeologists and others working in the field of cultural heritage. Reflectance Transformation Imaging (RTI) and three-dimensional (3D) modeling using close-range photogrammetry are two photo-based methods that are becoming increasingly common. They have the benefits of being both relatively inexpensive and portable, meaning these methods can be applied under a wide variety of conditions by workers at nearly all levels of funding. This paper discusses the results that were achieved by applying these techniques to a mobiliary art object from the Paleolithic site of Solutré (Burgundy, France) featuring fine engravings. We were able to successfully enhance the visibility of modifications made to the case study object using both RTI and close range photogrammetry. We conclude that these methods can be seen as complimentary, and that the resulting products may be used for several purposes including the creation of relevés, stylistic analysis, and the dissemination of digital object representations for both scholarly publication and public engagement.
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1. Introduction

In recent years, technological advances have opened up a world of low cost techniques for the documentation of archaeological objects. These include reflectance transformation imaging (RTI), which uses images lit from many different directions to calculate surface normals (Malzbender et al., 2001; Mudge et al., 2006; Schroer, 2012), and photogrammetry, which creates a three-dimensional (3D) model of a surface or object using matched reference points generated from a series of overlapping two-dimensional (2D) images.

Previous studies have compared the results achievable through the application of RTI and 3D laser scanning on archaeological materials (Diaz-Guardamino and Wheatley, 2013). RTI and 3D reconstruction using photogrammetry have also been directly compared on larger objects (Miles et al., 2014, 2015; Earl et al., 2010), but fewer comparisons have been made on a smaller scale (MacDonald, 2011). Here, we describe the results achieved through RTI and photogrammetry on an engraved plaque, which is approximately 11 cm in length and features very fine, shallow engravings.

2. Materials and methods

2.1. Artifact context

The artifact selected for this comparison is an engraved piece of schist discovered in 1907 by Abbé Breuil in a Solutrean context at the site of Solutré (Saône-et-Loire, Burgundy, France) (Fig. 1a). The artifact is curated in the Geological Collections, UMR 5276 - CERESE, University Lyon 1 (France). It is engraved on both sides, and at least two horses and several unidentified animalistic figures are purportedly depicted. These engravings are difficult to see with the naked eye and are barely visible in traditional photographs. A redrawing of the engravings by Jean Combier has previously been published (Fig. 1b) (Combier and Montet-White, 2002) but no further study of the piece has been undertaken until now.

2.2. Reflectance transformation imaging

As stated earlier, RTI images are generated from a series of photos that have been illuminated from different directions and angles relative to the target object's surface while the camera remains in a fixed position. In this case, we used the highlight-based version of the technique where light direction is calculated using the position of a spotlight reflected off a black sphere.

RTI allows digital, interactive control of lighting conditions, and can enhance objects surface details using different modulations of the

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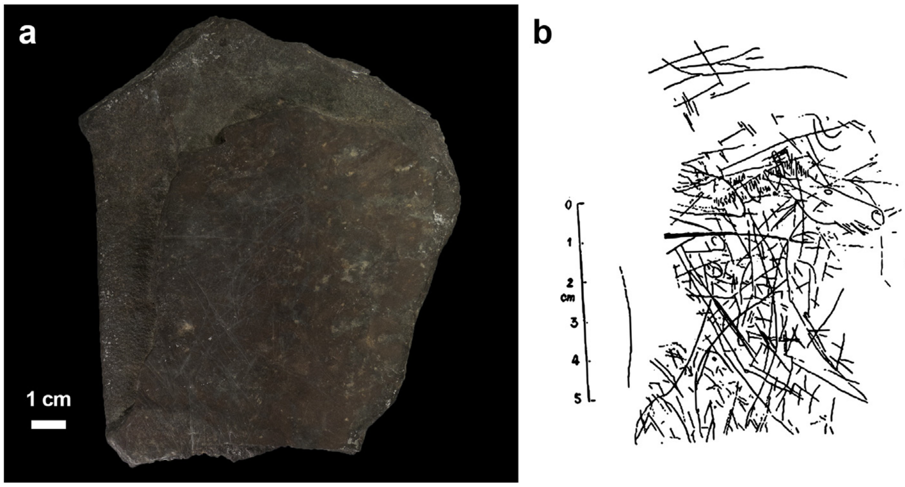

Fig. 1. Engraved Solutrean plaque; a) traditional photograph with direct lighting; b) redrawing of side 1 of the engraved plaque. (After Combier and Montet-White, 2002, page 256, Fig. 1b).

surface and its reflectance (Malzbender et al., 2001; Mudge et al., 2006, Schroer, 2012; culutralheritage.com).

Many different rigs have been designed to facilitate reflectance transformation imaging (e.g. Earl et al., 2011; Kinsman, 2016; MacDonald, 2011). These setups can be automated, and may not require the use of a reflective sphere. On the other hand, they can relatively unwieldy, may include moving parts, and may require some knowledge of wiring and programming. Because transportability was important to us, we constructed a simpler portable rig out of PVC sheets, which can be easily dissembled (Fig. 2a). It consists of an arm with small shelves that allows a small flashlight to be affixed at different heights and angles, and a circular ring to guide the placement of the arm at even intervals around the object being imaged. The simple nature of this rig also means there are fewer things that can render the setup non-operational. This is of special concern for researchers who work in relatively remote locations. Details about the RTI photography protocol we used for this object are available in this paper's Supplementary technical information.

2.3. Photogrammetry

To create a detailed 3D model, close up images were taken in several passes across the artifact's two principal surfaces. In order to produce a lower resolution model of the entire plaque, photos were also taken using the system and protocol described in Porter et al. (2016). Models were processed using the software Agisoft PhotoScan (2015). Further details about the photogrammetry protocol used to document object and are available in this paper's Supplementary technical information.

3. Results and discussion

3.1. RTI results

Even on an unenhanced RTI image, which is generated from a calculation of surface normals but has not been further optimized by filters, the surface morphology of the piece and individual engravings are more recognizable than they appear in a traditional photo (Fig. 3a and b). This makes the outline of the engraved horse much clearer.

In order to further enhance the image, different contrast operators were applied using RTIViewer (culturalheritageimaging.org). Specular enhancement (Malzbender et al., 2001) applies a special per pixel lighting model to add specular or diffuse shading effects (Fig. 3d). Color can be extracted completely, making it easier to focus on the engravings themselves. Due to the convex surface of the artifact, it was not possible to enhance the entire engraved area using specular enhancement. However, this operator delivers good results over smaller areas, such as the head of the horse (Fig. 3f).

To enhance the complete engraved area, we found image unsharp masking to be a more useful tool. Even extremely fine lines, such as

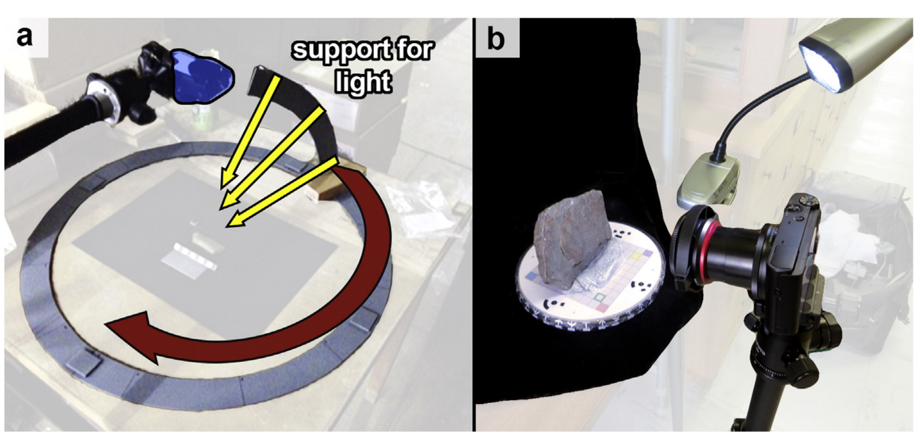

Fig. 2. The two rigs used to capture images for this case study; a) rig designed for RTI with camera position highlighted in blue. Yellow lines represent different angels of light utilized; b) setup used for detailed close range photogrammetry. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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