3D digitizing and visualizing a prehistoric portable art object: a 12,000 years old "bâton percé"

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Abstract
In this paper, we present some results on 3D digitizing and visualizing a prehistoric portable art object. This 12,000 years old artifact was scanned with a surface scanner and with two volume scanners (CT and μCT). With this last device, we can reach a high resolution (41μm) which allows one to distinguish the engravings. It is not so easy to visualize and interact in 3D with such a complex object and we describe a framework composed of a stereoscopic visualization system coupled with a low-cost tangible interface based on a Wiimote.

Categories and Subject Descriptors (according to ACM CCS): J.2 [Computer Applications]: Physical Sciences and Engineering—Archaeology

1. Introduction

Prehistoric portable art (also called movable or mobiliary art) can be defined as mobile items that could be carried from place to place, in contrast to cave art. The objects can be as simple as a shell which was drilled by the prehistoric man or very complex as a statuette carved in stone. Such items are fragile and valuable; it is then difficult to manipulate them either for conservation, restoration, analysis or for a simple museum exhibition. One solution would be to perform a 3D scanning in order to obtain a 3D digital (or a virtual) representation which could be easily archived, visualized and exchanged.

But, if 3D scanning of cultural heritage objects is now widely developed, there is still very few work on the specific field of prehistoric portable art objects. In this paper, we present some on-going research on the two following topics:

- test different 3D scanning devices and protocols. They must be adapted to the material of the object, to the resolution (does the expert want to study the overall shape or only the engravings?) and more generally to the required information (does the expert want to study the surface or the inside? Is the color of the surface important, for example to analyze some drawings?).
- test and develop some 3D visualization and interaction

tools which allow the expert to do research on the virtual representation.

For this purpose, an expert in prehistory selected a portable art object which is a "bâton percé" or "perforated baton". Such an artifact is typical of a prehistoric period called late Magdalenian (around 15,000 B.C.) and shows different levels of geometric details (a large hole, fine engravings). As the purpose of the "bâton percé" remains unknown (among the interpretations, we can find a symbol of power, a symbol of fertility, an arrow or spear straightener or a spear thrower), this kind of object is particularly studied.

2. Description of the object

La Madeleine is a rock shelter located in the Vézère valley in the district of Tursac in Dordogne which is one of the World heritage sites in France. It is the type site for Magdalenian, one of the latest cultures of upper Palaeolithic in Western Europe. During the second part of the 19th century, large excavations were conducted on this site by Edouard Lartet, one of the pioneers of research in prehistory.

Today, Lartet's collection belongs to several museums in France: National Museum of Natural History in Paris, National Antiquities Museum in Saint-Germain-en-Laye and

Figure 1: *Photography of the baton percé with a zoom on the engravings.*

Toulouse Natural History Museum. Among the numerous objects which were discovered in La Madeleine, many specimens of portable art were studied by researchers in Prehistory. During the renovation of the Toulouse Museum, an inventory of Lartet's collection enabled us to recover a broken bâton percé from La Madeleine. This bâton consists in a 10 cm long, decorated cylinder of reindeer antler with a hole through the thickest part and engravings representing the head of a horse (see Fig. 1). An examination of the other objects collected by Lartet led to the conclusion that the specimen from Toulouse is the complement of another fragment stored in Saint-Germain-en Laye. There is no record of the discovery so we do not know precisely in which stratigraphic level this stick was collected. However, the style of the engraving suggests Upper Magdalenian, around 12,000 B.P.

3. 3D scanning

Rather few research has been done on 3D digitizing prehistoric artifacts. In [BTS*04], several 3D scanning devices were used to digitize some stone tools and the results were compared qualitatively and quantitatively. Some mobile art objects have been scanned as the figurines, estimated to be 25,000 years old in [GBT*02], but it is more to demonstrate an acquisition device than for a real application in prehistory research. The Ishango bone tool, dated to the Upper Paleolithic era was also digitized by different volume and surface 3D devices (see [Til07] and [CSM08]) but, except some images, no detail is given. In the following, we present and assess the data obtained by one surface and two volume 3D scanning devices.

3.1. Surface scanning

3D surface scanners are often used to digitize heritage objects as they are portable, affordable and overall have been widely validated in industrial metrology. We used a prototypal handheld system developed by the start-up *Noomeo* [Noo10] which is based on structured light projection and claims a resolution of around 50 to 100 μm. The texture of the "bâton percé" was acquired independently by using a digital photo studio. The high-resolution photographs were then mapped on the geometrical mesh in a post-processing stage.

The resolution (see Fig. 2a) is visually sufficient for a museographic presentation, especially as we have the texture but it remains quite rough around the engravings. Nevertheless, the scanning process requires to register the 3D acquisitions taken from different points of views. This is more or less automated in the last generation of hand-held scanner but it remains quite tedious. It may also reduce a lot the accuracy if we do not use any external localization device as a mechanical arm or a photogrammetry system, which are not easy to set-up in the case of little objects. Moreover, even by multiplicating the points of view, we can still have some occlusions which we have to deal with by interpolating the geometry and the texture.

3.2. Volume scanning

Volume scanning (which is in general based on Computer Tomography) is now widely used to visualize and analyze prehistoric fossils (see for example [MGdLS04]) but not arefacts, even if they are made in bone. This is mainly due to the difficulty to access to the scanning devices which are located in hospitals. Nevertheless, these last years, several μ-CT scan devices have been commercialized. They present a higher resolution (around 20 to 40 μm or even less whereas it is up to 0.1 mm in the case of medical CT-scan) and they can be easily installed on a desk.

Contrary to the surface scanning, we get a volume acquisition (i.e. we can see the complete surface of the object as its interior) but we do not have information on the texture. Some algorithms must be used to segment (i.e. delineate), in the initial 3D image, the region of interest (in our case, the surface) and to extract a 3D mesh.
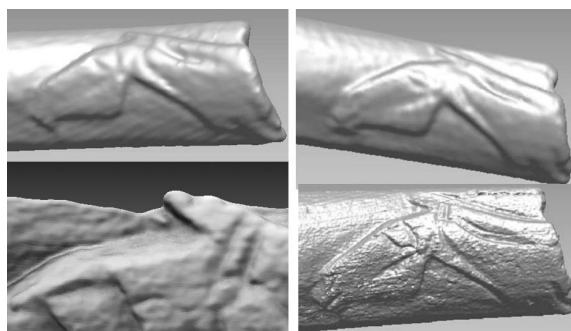

Figure 2: *3D scanning of the bâton percé: zoom on the engravings. Up: surface scanning (left) and CT-Scan (right). Bottom: μ-CT Scan (right) with a maginification around the horse ear (left) to visually estimate the accuracy.*

For the bâton percé, we used a medical scanner to get a 3D image of 154 slices of 512 × 512 pixels which corresponds to a resolution of 0.3 mm. This leads to a 3D representation[†]

[†]   A 3D mesh of the "bâton percé" obtained from the CT image is available at: *http://www.lirmm.fr/ODENT/dataBaton.html*

which has the same level of detail than with the surface scanning (see Fig. 2b) but the acquisition process is much quicker as there is only one acquisition and no registration of different views. With a Scanco Medical Xtreme μCT device, we got 2,780 slices of 836 × 908 pixels leading to a resolution of 41 μm. In this case, we distinguish very well the surface details as the engravings (see Fig. 2c) but data are so huge (4.6 Gb) that we have to process them by sub-blocks. Moreover, the image is more noisy and we must be very careful in the segmentation step: for example, the foam which supported the "bâton percé" is partially visible in the image and prevents one to have a clear segmentation of the surface at some points.

4. 3D visualization and interaction

As the scaning process leads to a huge dataset, the visualization part must be handled with care so as to offer a precise and convenient manipulation of the virtual model for the researchers as well as for a presentation to the general audience. In this project, the software visualization is based on OpenSceneGraph (OSG) [Ope10], which can render large and complex 3D models at a realtime rate in stereo.

4.1. Visualizing large datasets

OSG offers in particular an easy mechanism for managing a Level of Detail (LOD) structure [LRC*02]. The objective is to display a detailed part of the object (high LOD) when the viewer is near whereas a simplified version of the 3D model (low LOD) is displayed when the viewer is far. By combining two parameters - the required resolution and the field of view- we can display a number of triangles which is always of the same order of magnitude, maintaining a constant rendering framerate. In OSG the LOD is modeled as a group node switching among children depending on the distance of the model from the eye point.

In our application, we used 3 different LOD, the 3D mesh in full resolution (652 Mb), in mid-resolution (60 Mb which is a reduction by 1/4) and in low resolution (5.4 Mb, reduced by 1/8) which allows one to display in real-time on a standard PC with a powerful graphic card.

4.2. Stereoscopic visualization

OSG allows many different ways to display the 3D scene in stereo. When it is supported by the hardware, it is worth using OpenGL Quad Buffer technology. In this case, the graphical buffers are rendered independently permitting a smooth stereoscopic display, the front left and front right buffers displaying the stereo images are swapped in sync with shutterglasses while back buffers are updated.

We have used an active stereo rendering system (see Fig. 3), composed of a DepthQ projector and LCD shutter glasses synchronized by an infra-ted emitter. This solution enables a

powerful configuration with an easy setup at a quite affordable cost.

Figure 3: *Details of the hardware used for visualizing and interacting with the bâton percé: 1. DepthQ 3D projector for active stereoscopic projection; 2. NuVision 60 GX stereoscopic wireless glasses; 3. infra-red emitter for synchronization with the glasses; 4. Wiimote wireless device.*

The visualization of the bâton percé in stereo allows one to observe a lot of detailed information, in particular to apprehend the shape and the depth of the engravings (see Fig. 5).

4.3. 3D interaction

A key point for using such data is to have a convenient interaction with the virtual model. The idea is to use a tangible "metaphor" of the object in order that the user will use it naturally and then, forget it very quickly, being focused on the image projected on the screen.

Figure 4: *The Wiimote device with the Wii Motion Plus.*

As a tangible interface, we used the Wiimote which is the famous wireless device communicating with the Nintendo Wii gaming platform. Its rectangular shape is particulary adapted to represent the bâton percé as we can see in Fig. 4. Moreover, this low-cost device is being used for many

interaction applications [Lee08], in particular to manipulate data from 3D medical images [GPM08].

As the Wiimote uses the Bluetooth communication protocol, it is very easy to connect to a standard PC. Moreover, the use of the Wii Motion Plus, an addon containing two gyro sensors used to measure the rate of rotation along the 3-axes, X (pitch), Y (roll), and Z (yaw) makes it possible to have 3 DOF tracking information. The communication between the Wiimote and the PC has been coded using the Wiimuse [Wii10a] and WiiYourself! [Wii10b] libraries which supports the Motion Plus addon.

A simple trigger of the button on the back of the Wiimote freezes the virtual object, allowing the user to control wether he wants to enable or disable the manipulation of the 3D model. This makes it very intuitive to reposition the hand in order to continue to manipulate the virtual object to make, for example, a complete turn. We have already prepared the application for the manipulation of two pieces as in [RRS*07] with 2 Wiimotes.

Figure 5: *Presentation of the engravings of the bâton percé to the general audience.*

5. Future work

In future work, we plan to study the engravings in the μCT data. By using some algorithms as the one described in [ZTS09], we plan to detect automatically the ridges on the surface and extract the depth and the profile of the engraved lines. By comparing their depths when they cross, we can deduce in which order they have been performed. It is also possible to deduce which tool was used by analyzing the shape of the profile (for example, is it U- or V-shaped?) and even get precise information of the engraver's gesture (beginning point, sense of execution, inclination, etc.) [Fri99]. This will help the paleontologists to formulate hypotheses on the technical and artistical skills and apprenticeships of our ancestors.

Acknowledgements

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