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3D enhanced model from multiple data sources for the analysis of the Cylinder seal of Ibni-Sharrum

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Abstract

In this paper we present the result of the integration of multiple data sources of different 3D acquisition techniques. These acquisitions have been done in order to create a new way to document works of art that have been applied to the "Cylinder seal of Ibni-Sharrum".

X-ray tomography has been used to reveal the exact position of inclusions and the presence fissure in the mineral structure; optical micro topography gives the prints of the surface of the seal with a unparallelled precision of up to 0.1μm. Finally a lower resolution 3D model obtained via photogrammetry has been used as a starting point where the tomographic and micro topographic data sets have been superimposed and integrated without precision loss. Furthermore, the textures obtained from HDR photographs has been registered and merged onto the high resolution mesh. These methods have pros and cons that will be discussed and the final obtained model will be the sum of all the complementary cons.

The final result of this interdisciplinary investigation will help the curator to better describe the fabrication techniques used in order to achieve the final object and a contemporary artist to do a reproduction of the cylinder at a scale of 1000:1.

Categories and Subject Descriptors (according to ACM CCS): I.3 [Computer Graphics]:

1. Introduction

The seal of the scribe Ibni-sharrum is one of the finest examples of carving in miniature [Ami76]. Produced during the Agade period, under the reign of Sharkali-Sharri it can be dated around 2217-2193 BC. The two naked heroes are symmetrical and half-kneeling and they hold vases from which water is gushing. Two buffaloes drink from this water.

As we can see in Figure 1 the object appears to be finely engraved, with delicate drawings organised in an elegant composition that make this seal one of the masterpieces of glyptic art. Small cylindrical seals such as this were quite common in ancient Near Eastern civilisations but they are often eclipsed by more monumental works. A perforation is present along the highest axes.

The elementary chemical composition of the stone have been determined using the PIXE technology (Particule Induced X-Ray Emission) and then the mineralogical composition has been identified using XRD (X-Ray Diffraction). The use of the particles accelerator located at the Centre de Recherche et de Restauration des Musées de France (AGLAE, Accélérateur Grand Louvre d'Analyse elémentaire) for the PIXE gives us enough information to classify the stone as a black "diorite". Furthermore, the physical analysis allows us also to discover the presence of some pyroxene into the object that maybe might be helpful to identify the provenance of the mineral used.

To document this incredible monument in miniature we have adopted an experimental protocol to support the photographic information with data coming from different techniques and integrated in one, complete, complex, rich

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Figure 1: *Cylinder seal of Ibni-Sharrum and its development on clay, inv. n. AO22303, Oriental Arts dept., Louvre Museum*

model. This enhanced 3D model contains information originate from X-Ray computed tomography, μ-topography, photogrammetry and high resolution images. Data's spatial resolution vary from macro (photogrammetry, precision in order of millimetres) to micro scale (μ-topography, precision up to $0,1\mu$m).

This interdisciplinary experiment represents a new, unexplored and, until now, unexploited way to document objects and works of art in a Cultural Heritage environment such as the C2RMF and the Louvre Museum.

2. 3D Acquisition process

Image and 3D data acquisitions in the field of Cultural Heritage are not always an easy task. The heterogeneity of the collections is so big that there is not a fixed, well described approach but people must take into account a series of circumstances and adapt each method depending on the object studied.

In this case the cylinder is very dark with varying green/brown reflections and it is predominantly shiny. This means that we will be unable to use any laser techniques on the object because the dark colour absorbs the spectral information from the laser light and the reflectance gives us wrong data about the real position of the laser on the surface. A valid alternative is to acquire the object via photogrammetry.

2.1. Computed Tomography

The first radiography on a painting done at the C2RMF was carried out in 1920. Nowadays non destructive methods of diagnosis based firstly on x-ray digital radiography (DR) and then on computed tomography (CT), are more and more used for the conservation and restoration in the cultural heritage field. In particular this kind of analysis can help not only to survey the state of the object (Figure 2) but also to understand the construction techniques of the object under examination.

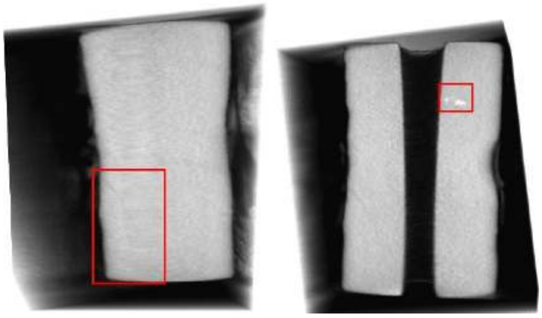

Figure 2: *X-ray Computed Tomography: (left) in evidence the crack inside the stone; (right) the small inclusion, with a higher density*

The use of x-ray tomography for objects is a big step forward in the interpretation of data compared to digital x-ray systems. Computed tomography gives us the possibility to exactly measure certain details, for example in our case, the variation of the diameter of the perforation in its centre.

Disadvantages of the use of computed tomography technique is that it is difficult to use and expensive. In fact, to produce good tomography 3D models, many hundred digital radiographies are necessary and the equipment to achieve this is very expensive. The obtained model is unfortunately not exempt from noise and the final shape is slightly deformed depending from the position of the detector. In order to have useful results and avoid meaningless data the system and the acquisition conditions must be chosen carefully.

2.2. μ Topography

This technique, also called optical roughness-meter, is based on a quasi confocal, z-axis extended field. This axis field ex-

Figure 3: *X-ray data visualised using MeshLab*

tension is obtained by stretching the axial chromatism generally encountered in a confocal dioptric setup when working with a polychromatic point source. That means that we know the z axis of the point via the wavelength of the univocal colour back-scattered [EBB*07].

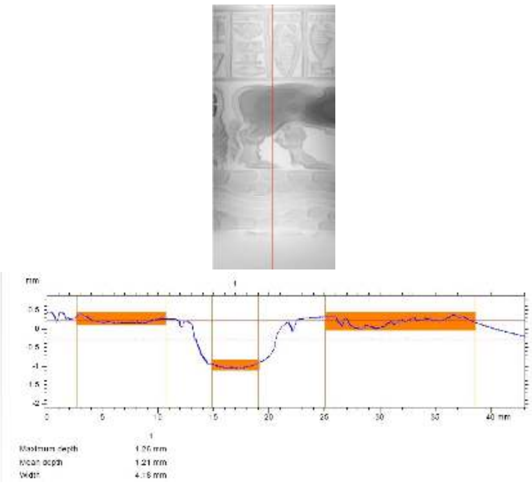

Figure 4: *μ-topography: line of measure and its values*

Coupling this complex optical technique with a translation table in x, y we are able to acquire surface portion and thus obtain a micro-topographic image of the surface to analyse. Even if this technique is very time consuming it gives very good results and the geometry of the "scanned" surface is highly precise, up to $0,1\mu$m. On the other hand with this approach, we do not, yet, have colour information, there are unacquired areas, and the data we have is local information.

2.3. Photogrammetry

Different photogrammetry methods are described in literature and each one have its characteristics. From 2004 at the C2RMF we use a method called Hernandez-Schmitt [HS04]. Starting from a calibrated sequence of colour images, the algorithm is able to reconstruct both 3D geometry and the texture. The method is based on a deformable model, which defines the framework where texture and silhouette information will be fused. This is achieved by defining two forces: one driven by the texture and the second driven by the silhouettes.

Figure 5: *Photogrammetry: the top and the bottom of the model are not visible*

The quality of the resulting texture is very high, comparable to the originals photos, the equipment is not expensive and the data are not local but about the total geometry of the model. A disadvantage is the very long time needed in order to extract precise silhouettes and the fact that the final model has a medium/low topographic quality.

3. Data Processing

Because the heterogeneous nature of the source of data, we need a versatile tool to be able to manipulate this huge amount of information. MeshLab [CCR08] represented for us the solution both for its fairly mature stability and for the open source characteristic of its code. The possibility to access the code has been very useful because the data issues

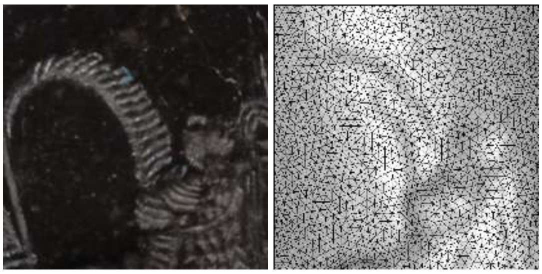

Figure 6: *Photogrammetry: details of the resulting model*

of proprietary software was not always in the proper format, as we will illustrate in the followings paragraphs. Therefore, we had to develop some additional modules.

3.1. Data format normalisation

Apart from the software used to export the computed tomography model, that saved the final result in `STL` format, both photogrammetry and μ-topography required the development of input plugins for MeshLab. The first, photogrammetry, saved its models in `TRI`, a binary format created to store information about the photogrammetry parameters and variables and the second one, export its data in `ASC`, a text format where the data are organised for a fixed step in x, y and printed out the z values.

3.2. Multiple data fusion

The original μ-topography data contained a lot of automatically filled portions corresponding to the area that the device was not able to acquire (Figure7). These filled portions were done by a smooth interpolation approach that while useful in most cases was not the best option for the case of integration of multiple data sources.

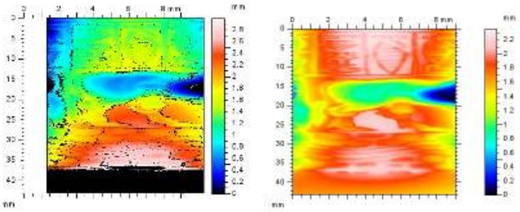

Figure 7: *μ-topography: the result of the automatic area filler*

In fact we had to remove the above mentioned portions and substitute them with the corresponding low resolution 3D data that came from the photogrammetric reconstruction. The photogrammetric 3D data even though it was at a resolution and precision much lower than the data acquired from the μ-topographer it was indeed consistent and a much better guess than the simple interpolation algorithm used by the μ-topographer to interpolate missing data.

The merging of the range maps obtained with the μ-topographer was done using the Poisson surface reconstruction tool inside MeshLab that is based on the code kindly provided by the authors of the original paper [KBH06].

To correctly insert the tomographic data we relied on the Alignment tools inside MeshLab. We aligned the exterior of the computed tomography (CT) reconstruction of the Seal with the seal reconstructed with the integration of μ-topographic and photogrammetric data. Once aligned we discarded the portion of the CT data that were covered by better quality 3D data in a automatic way leaving only the internal hole of the seal and with the surface of the inner pyrite inclusion. We brought in this remaining surface data and we run again the Poisson surface reconstruction algorithm that merged all the 3D sources. Then we weighted the input data with their accuracy so that more accurate data was preferred when it was available.

Acting in this way we automatically used CT and photogrammetric 3D data only for these portions of the model that were not covered by the μ-topography data. In particular we used the computed tomography data only for the inner hole and for the inclusion because of the high level of noise on the surface.

3.3. High Resolution Image Registration

For the alignment of the photographic data over the mesh we have used the approach proposed in [FDG*05] that allows to find in a user assisted way the intrinsic and extrinsic calibration parameters for a given set of photos over an existing scanned 3D model.

Once the photos have been registered onto the seal model we used the technique described in [CCCS08] to merge in a seamless and coherent way the colour information contained in the photographic data. The obtained colour was stored following a colour per-vertex approach that avoid the need of a direct texture parametrisation of the surface of the seal. The achieved result is visible in figure 8.

4. Results and Exploitations

This original exploitation of the images in a 3D space, permits us to do an innovative reinterpretation of the work of art showing up to the traces of its creation and give us the basis for a new documentary tool based on 3D imaging.

Once the enhanced model is finalised (Figure 9) it can be used in many, different ways, for example, in the physico-chemical research field, to focus the research in the precise point where the inclusion or the crack is; or to better document the object itself using more detailed images, models

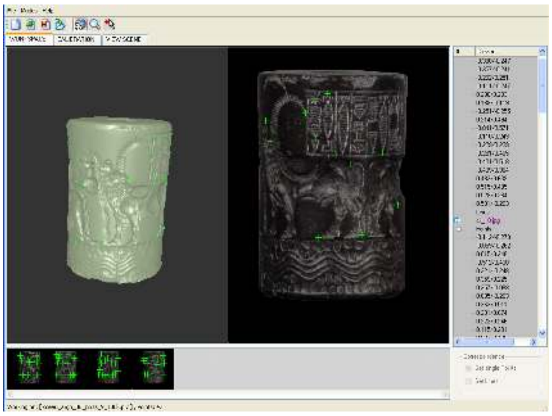

Figure 8: *A snapshot of the TexAlign tool for registering photographic data over a 3D mesh. Some of the original photogrammetric images are used as a source for recovering the surface colour. The small green cross-hairs show correspondence points between images and the 3D surface.*

and information; or prototyping it for educational purposes as illustrated in figure 10; or, as a contemporary artist propose, to re-sample it in a bigger scale to better explain to the public how difficult it is to work this matter and to attract the attention of the public to an art older than 4000 years.

In figure 10 we show two reproductions, one (left) done with the standard rapid prototyping techinique and the other performed (right) with an automatic color enhancement alghoritm that put in evidence the small features of the seal using the technique proposed in [CGPS08]; this recently proposed approach allows to obtain a better readibility of the shape of the objects reconstructed using standard rapid prototyping techniques.

Another interesting achievement of this modelling has been the development of a simple, but efficient module, inside MeshLab, to unwrap our model along the vertical axes (Figure 12. This will help to prevent these cylinders to being printed again over the time avoiding possibility of accidents or deformation or simple pollution like in figure 11.

Figure 9: *The final model sliced by a x,z plane showing the inner hole and the inclusion detail.*

Figure 10: *A first attempt of prototyping.*

5. Conclusion

Diorite is an extremely hard stone (close to the hardness of glass), harder than granite, which means to engrave or cut is very difficult. This stone is so hard that ancient populations used it to sculpt granite. This means that to have achieved this small masterpiece an intense work and a in depth knowledge of how to work that particular stone was necessary. More research is now needed in order to understand what were the techniques used by the scribe 4000 years ago. The 3D model and the tool we provide are a good point to start a reinterpretation using a new perspective. It is obvious that this kind of investigation can only be carried out in an interdisciplinary context where art historians, conservation scientists, scientific researchers and photographers share their knowledge and their skills.

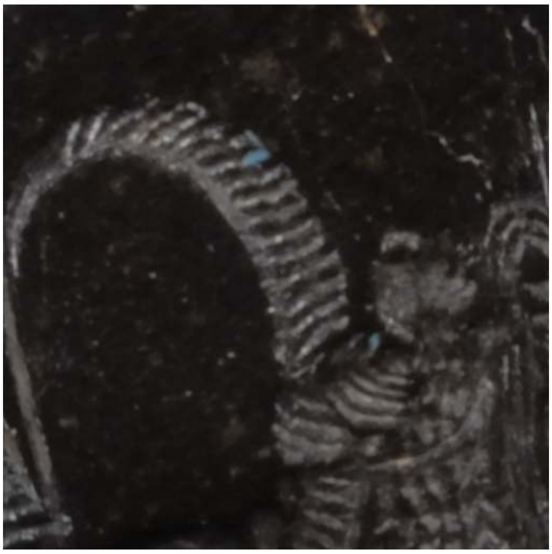

Figure 11: *Some plasticine (in blue) probably from a previous impression.*

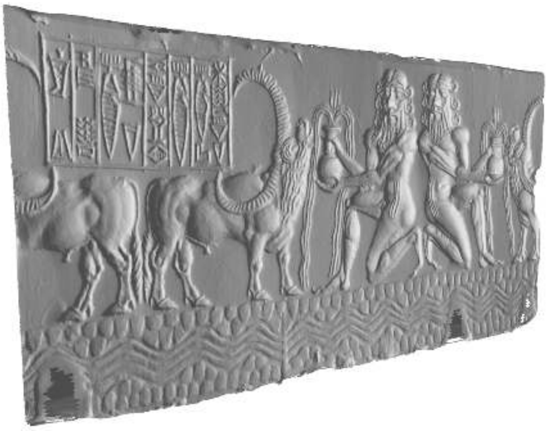

Figure 12: *Resulting unwrapping of the cylinder in negative, the same result can be obtained in embossed effect.*

6. Acknowledgements

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