Photogrammetry of Cast Collection, Technical and Analytical Methodology of a Digital Rebirth

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Before the use of photography and digital projections, cast collections had a major place in Archaeology and History of Art studies. Replacing the original content, they permitted in different manners to touch the past in a safety and unobtrusive way: watch, touch and manipulate the cast allowed proactively students to learn the techniques of the ancient masters. Nowadays cast collections lays in university corridors or in museum storages waiting to be restored due to their material properties, the degradations of time, and the difficulty to use them in a course. Thinking about their past didactic roles, the Université Libre de Bruxelles wanted primarily a way to restore and preserve her antique study cast collection and, in the same way, give it a new sight as a nowadays collection study. For three months, in the same time of cast restorations, PANORAMA team has developed a photogrammetric workflow to produce and treat photographic shooting, texture delighting, point cloud reconstruction, meshing, retouching, simplifying, retopologizing, relighting and at the end of the whole process, web publishing. Through this paper the PANORAMA photogrammetric reconstruction methodology will be introduced and particularly the texture delighting process developed to enhance texture details and easily reintegrate models as a fully usable 3D asset in any 3D scene.

INTRODUCTION

As a precise surveying technique based on theories and optical experiments of Leonardo da Vinci [da Vinci 1970] around 1480, the principles of photogrammetry were born in the 17th century, when Desargues added the notion of vanishing points [Andersen 1991]. It was not until 1840 to move from theory to practice, under the aegis of François Arago [Arago 1939], who used this technique based on a daguerreotype, ancestor of the film camera. In 1849, modern photogrammetry was born from Aimé Laussedat's novel idea of using a set of photographs to measure the façade of the Hôtel des Invalides in Paris. This method has underwent many evolutions, especially under the aegis of Felix Tournachon, said Nadar, inventor of aerial photography, who in the 1860s, mounted in balloon to photograph the city of Paris for a map, both civilian and military. The surveying practice then had to wait for the material improvement developed during the interwar period completed later by the advent of satellite photography, the birth of computer science and the robotics.

Thanks to the contribution of digital photography and the computer and programming advancement in this field, offering the possibility of making and processing hundreds of shots by subject, photogrammetry

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seems to be, at first glance, a simple technique to set up and to reproduce inexpensive complex three-dimensional models such as cast collection from the Université Libre de Bruxelles. Nevertheless, the use of the photogrammetric techniques would make it possible to gather the whole of this collection in a virtual museum, easily accessible by all; but it requires many ancillary treatments essential to respect these constraints of accessibility and use.

PHOTOGRAMMETRIC WORKFLOW

The current workflow involves many colorimetric enhancements and corrections of photographic data. The photogrammetric process is then followed by the geometric correction of the models, their weight and the constitution of PBR shaders from their textures. This linear workflow intends to make on internet the entire collection of plaster statues of the Université Libre de Bruxelles available for web browser. Fig. 1 summarizes these different steps.
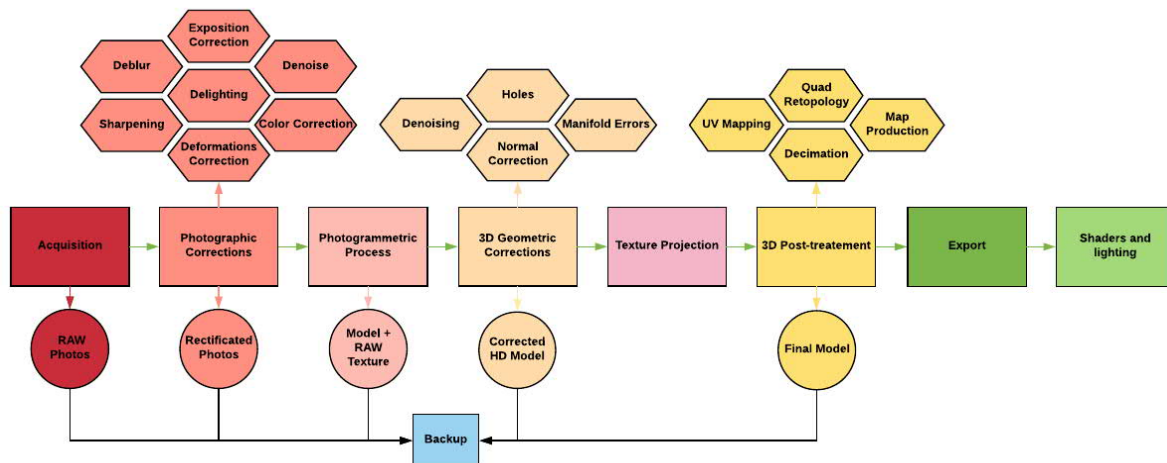

Fig. 1. PANORAMA Photogrammetric Workflow

ACQUISITION METHODOLOGY

The methodology for acquiring three-dimensional reconstruction data of a work or architecture must be as logical as possible in order to limit the number of shots and unnecessary calculation time, while reducing the post-processing time in photographic and infographic. Several elements have to be taken into consideration:

- The purpose of the 3D model, which defines the needs in terms of texture and colorization, as well as the quality to adopt when taking data and the 3D treatments to apply a posteriori: paper publications, web publishing, virtual reality, reconstruction, schematic modeling, research, etc.

- The size of the real model: object of small, medium or large size

- The deadlines of the acquisition mission

- The accessibility of the real model and the logistics to deploy in order to obtain a complete model: constraints of the acquisition area (heavy or non-heavy equipment, impaired vision, reduced accessibility, etc.)

- The type of lighting (outdoor or studio) needed to obtain quality textures

- From these non-exhaustive constraints, it is possible to determine, in a more or less reliable manner, the methodology to adopt for providing the best model

- To allow accurate photogrammetric reconstruction with detailed texture, all the acquisitions were made using a prime lens on DSLR - 12Mpx Fuji S5 Pro in full manual mode with Nikkor Ais 35mm f2 - on stable tripod with 80% of overlapping between each pictures and a maximum cross angle of 30° between frames
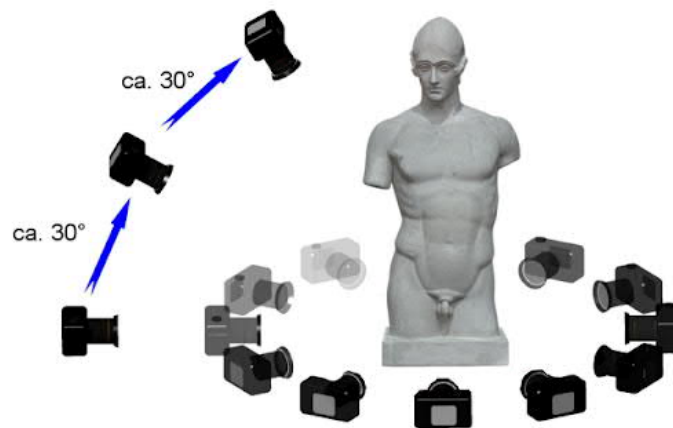

Fig. 2. Data acquisitions

- The aperture was constant and combines the sharpest opening and the best depth of field. By the way, the data acquisition followed all those predefined photographic rules to obtain the best result during the photogrammetric alignment process:

- Never limit the number of pictures: always try to cover the entire subject with a 15 % to 20 % overlap between shots to facilitate the alignment procedure, but a safe shot should contain an overlap of 60 % to 80 %.

- Work on the lowest ISO measurement (64, 100 or 200) to avoid any noises in the resulting image.

- Use the highest resolution: this add more control points and give a better detection during the alignment procedure.

- Photogrammetry is not a panoramic shooting (static shooting). Unlike panoramic photography, the subject is fixed and the photographer must cover all its surface. The alignment process takes into account the background of the subject.

- Do not change the view angle more than 30° (in any axis). To make a larger angle change, it is necessary to produce intermediate shots.

- In order to identify important details when shooting, it is advisable to focus on them (an additional picture during the shooting process and not after).

- For full 3D subjects, it is necessary to take a complete cycle of pictures around the subject and not to take a spiral shot.

- To avoid any problem of Bokeh Effect and thus keeping maximum background information of the of the subject, it may be preferable to place the diaphragm aperture at least to 22 for a 35 mm lens, the light input will be minimum, the shutter speed will be reduced in long pause and so need the use of a tripod will be imperative!

- The picture focus point is made on the closest part to the lens of the subject.

- Depth of field will determine the number of shots: all fuzzy parts deserve the 3D reconstruction. These parts are useless and it is better to reduce the view angle to the perfectly developed zones and to adapt the pictures overlap.

- Working in autofocus mode is advantageous when it comes to a respectable size model. However, on small sizes subjects or in low light, it is necessary to disengage the camera and work in manual focus mode.

- Freehand shooting is quite possible, as long as the shutter speed is greater than 1/60 of a second. Below this shutter speed, it is better to attach a tripod and a wired trigger connected to the camera.

PHOTOGRAPHY CORRECTIONS

The photographic correction or photographic pretreatment will depend heavily on the preparation of the shooting. Two important photographic corrections are noted: optical correction and color correction.

The majority of photographic lenses introduce deformations of several types. The straightening of these deformations is one of the logical steps of photogrammetry programs. Nevertheless, this geometrical processing by the photogrammetry programs is not sufficient and need the use of specialized programs which perfectly manage these deformations taking into account the couple camera and optical using a recognized reference database (LCP profiles).

Optical distortions affect all objectives, to varying degrees, depending on their quality. High-end lenses are, in principle, better corrected. These distortions mainly affect straight lines and can be classified in 3 classes:
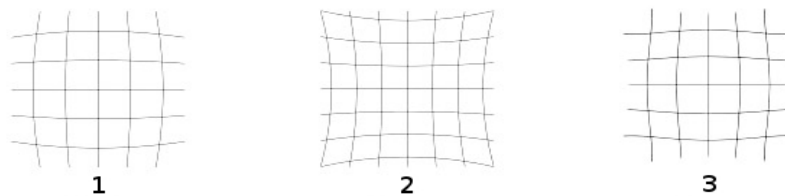

Fig. 3. The three types of lens distortions

1. Barrel distortion: the lines are curved outward from the image, cylinder-shaped like a small barrel. This usually affects long-focus lenses such as zooms. On "fish-eye" lens type, this barrel distortion becomes circular.

2. Pincushion distortion: the lines, especially at the periphery, are curved towards the center of the image, like a cushion that is crushed. This usually affects short-throw lenses, such as wide-angle lenses.

3. Fish-eye distortion: equivalent to pincushion distortion, but more pronounced.

Every photographic shooting must be done with a reference image including a color chart to correct the white balance, the intensity of the blacks and calibrate the colors. It is essential to not neglect this step which will allow in post-production to recover real values modified by the intrinsic and extrinsic parameters of any camera.

UNLIGHTING SCRIPT

To improve the images content, it is proposed to successively apply various operations as proposed by Schenkel [2017]. First of all, many pictures acquired during field surveys may have poorly exposed areas due to the acquisition parameterization and surrounding conditions (low light, specularity, etc.). The luminosity is thus corrected using a local gamma correction method. The local gamma factor is based on a mask defined as a low frequency monochrome version of the original image, avoiding to the chromicity of the image; while the deletion of high frequencies allows keeping the contrast of the image. Indeed, the impact of the mask is such that a pixel will be darkened especially as the value of the mask is large, and vice versa. So if the mask is a simple monochrome version of the original, the resulting image may lose its contrast. In contrast, the use of an image blurred to the extreme is to use a constant and a conventional gamma correction. This method has several advantages. The use of a low frequency mask causes progressive color correction through the image without artifacts. Extreme values are also preserved, as well as the pixels of the most complex regions. This correction makes it possible to relatively attenuate the highlights, as well as the main shadows, without introducing too much additional noise.

However, the results depend on the method to produce the low frequency mask. The adaptive filter introduced by Meylan and Süsstrunk [2006], which consists generally of a Gaussian filter limited by the edges in the image, determined with a Canny filter, give the best result. Indeed, mean and Gaussian blur results show more limited color corrections at the edges and brightness transitions; they introduces artifacts into the colorization (halos are noticeable at the level of luminosity transitions).

In a photograph, areas of blur are also often present, due to a problem of focus or autofocus, shaking when triggering, bad adjustment of the lens, a movement in the scene or insufficient brightness at the time of shooting. This results in a loss of quality at the object boundaries. Our experience in this case is to enhance the sharpness by reinforcing the high frequencies and thus increase the contrast at the edges without altering the colors or increase the imperfections of the image.

A simple method is to use an "unsharp masking" mask, a high-pass filter obtained according to the difference between the values of the original image and a version rendered blurred by using a low-pass filter. It is preferred to use image conversion in the HSV or CIE LAB color space, and restrict the approach to V or L components to avoid color distortion when sharpening. Thus, to obtain the image with accentuated details, it is sufficient to combine the initial image and this high-pass filter.

Finally a simple global increase in contrast is applied to restore the low hue losses inherent in previous processes. All of these corrections make it possible to obtain a noticeable visual improvement; by limiting overall noise increase to the initially darkest areas (shadows ...).

POST-PHOTOGRAMMETRIC TREATEMENT

The polygonal model obtained at the end of the photogrammetric process is not usable due to the large amount of data to be processed (triangles of the 3D model and texture resolution). The HD model can only serve as a starting point for a workable and publishable model. The making of a final polygonal model is therefore not limited to the simple photogrammetric stage, because producing an untreated deliverable. It is important to correct certain aspects, at both the three-dimensional and the color level, by going through various stages of correction including

- Correction and cleaning of the polygonal mesh to eliminate artifacts such as unsmoothed spikes, excess meshes, polygonal aberrations, mesh holes, and manifold errors. Fig. 4 highlights these common artifacts in 3D modeling, as well as the results obtained after their treatment.

- Polygonal simplification of the model to reduce the amount of geometric primitives to make it usable on common computers or for a smooth publication in a web player.

- Retopology or streamlined Quad Polygonal Mesh [Bommes et al. 2012] for optimization in 3D rendering engines. The results of the simplification and retopology of a model are illustrated in Fig. 5 for a high resolution model.
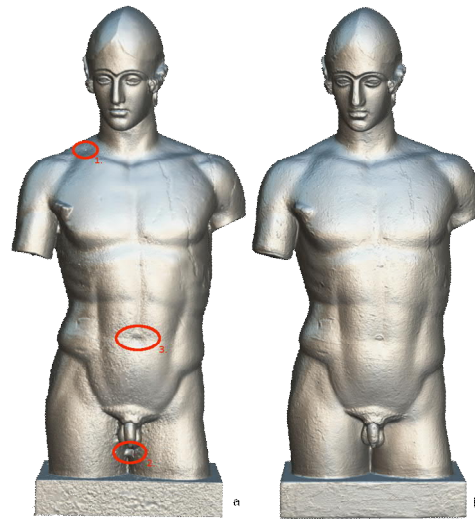
Fig. 4. Geometric model correction, tip smoothing and hole plugging can be observed between the uncleaned model (a) and the corrected model (b). Different problems are put forward on (a): 1. holes, 2. geometric artifacts and 3. deformations
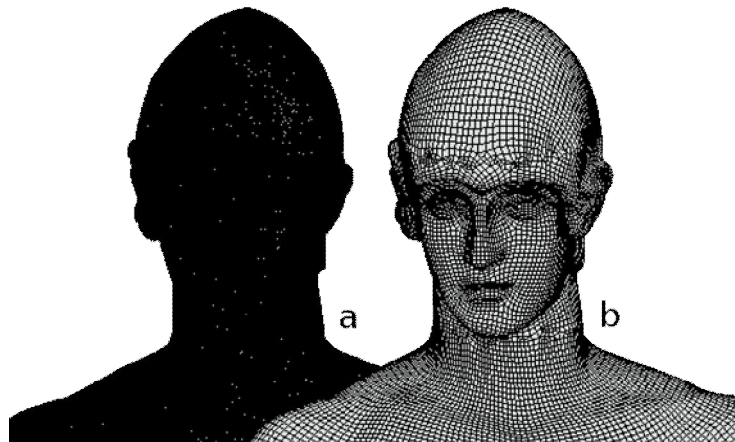

Fig. 5. Model decimation and retopology : (a) triangular model of average resolution (745.8 k points) and (b) retopologized model in quads (64.1 k points)

To be able to simplify the polygonal model, while preserving the impression of relief, the technique of normal mapping is used; it consists in transferring the elevation and inclination information from the surface of the geometry to a specific texture, called the normal map [Heidrich and Seidel 1999]. In addition to the use of a color texture, a graphics engine can emulate the shading and local geometric variations of the surfaces, thus making the appearance of relief and roughness.

To keep global surface modifications as well as local details (roughness), two normal maps are computed and merged. The first (see Fig. 6b) is obtained by projection of the normals at each point of the high-resolution model in the UV space of the textures; while the second (see Fig. 6c) is obtained by the colorimetric variations of the object (see Fig. 6a). Since the data represent directions, a simple linear interpolation or the individual processing of each

component does not make this combination possible; for this purpose (see Fig. 6d), it is preferred to use the fusion approach of Zioma and Green [2012].

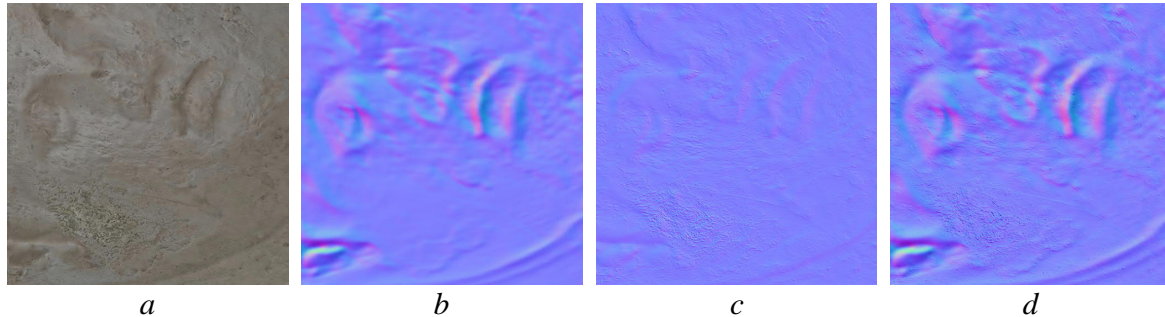*a*   *b*   *c*   *d*

Fig. 6. The first normal (b) is obtained by projection of normals at each point of the high resolution model in the UV space of the textures; the second (c) is based on the colorimetric variations of the object (a); (d) result from the Zioma and Green fusion of (b) and (c)

Finally, a UV card mapping (UV Mapping [Mullen 2012]) of the model texture is made. The method consists in rationally unfolding the model in the form of a plane map; that is to say, keeping as much as possible the topology of the object avoiding cutting into a large number of pieces, allowing an optimal use of the surface of the texture and the possibility of carrying out easy colorimetric retouching. For this, a re-projection of corrected textures of the high-definition model is performed on the decimated and retopologized polygonal model, through a script developed through an automated inhouse blender script developed by Q. Elias and improved by S. Fachada-Dury.Fig. 7 illustrates the differences between standard and streamlined UV card plating. This makes it possible to obtain an exploitable, lightweight and optimal model on any rendering engine.
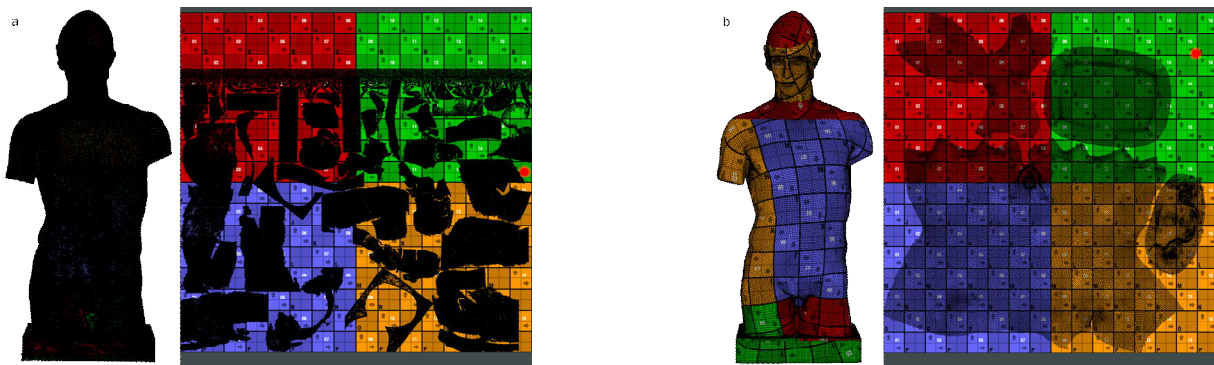

Fig. 7. Streamlined reprojection of textures : (a) texture and model obtained by photogrammetry and (b) decimated and retopologized model, as well as its rationalized texture.

RESULTS

The acquisition and processing of the 13 models, made from a total of 4486 photographs, were spread out over 2 months of time and required the participation of a photographer for taking the images and the managing the lighting, a 3D graphic designer for 3D retouching, as well as the active participation and scientific contribution of a computer scientist to the development of the pipeline.

From these models, we have developed a real-time virtual museum scenography, available on the internet that anyone wishing to discover the collection of antique plasters from the Université Libre de Bruxelles can visit at their ease. Each virtual museum component has a cartridge with annotations and a direct link to the online high definition model. Fig. 8 gives a rendering of the virtual museum thus constructed.

However, without the different stages of processing, the virtual museum, which brings together all the digitized plasters, could not be completed, because of limitation of data volume imposed by the web rendering engine (250 MB maximum, model and textures included) and the quality/time ratio of loading the model on the internet for the user.

Fig. 8. The virtual museum, including all the photogrammetric models, annotated to inform the user and made available on the internet

CONCLUSION

The project of digitization of the Université Libre de Bruxelles Cast Collection has focused only on the restored pieces of a particular chrono-cultural period representing only a tiny part of the inventory of acquisitions over time by our institution.

The pipeline is constantly evolving and adapting to many subjects using methods such as macro-photogrammetry, focus-stacking, RTI, virtual tours, virtual reality, 3D printing and CNC, lasergrammetry or drone survey. PANORAMA platform hopes to regularly expand the representative panel of the University's collection and to share it both with researchers and the public, and even extend it to external collections.

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