3D Modelling of Cultural Objects in the V&A Museum: Tools and Workflow Developments

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Abstract

Scholars require images of cultural heritage (CH) objects to assist them with their research. Just as for decades the art historian was satisfied with black and white images and indeed had difficulty in both trusting and using colour images when they were first made available to them, 3D imaging now faces similar questions for the scholar. They do not yet fully understand it's potential. One of the purposes of this paper, which is written as a result of work undertaken within the 3D COFORM EU funded research project, is as an educational exercise for scholars. Comparing results from different cultural objects made from a variety of different materials will enable scholars to better judge the technological potential and then predict when it will be useful and for their work.

The work at the V&A Photographic Studio has been undertaken in collaboration with Breuckmann GmbH and has used their Smart Scan-HE structured light scanner. Training Photographic Studio staff in the use of this new technology was part of the trial. Rates of learning and understanding of the medium were addressed to provide a better knowledge of the effort required to adopt 3D as a routine tool. A wide range of cultural objects was scanned from stone and wood sculpture to textiles and silverware. An analysis of the success of these was made and the results validated by discussion with V&A curators. This paper will illustrate this work and draw conclusions on the workflow developed

Introduction

This paper describes a trial undertaken in the V&A Museum Photographic Studio as part of the EU FP7 project 3D-COFORM. (The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007 2013) under grant agreement n° 231809.)

The 3D-COFORM consortium has one over-riding aim: "to establish 3D documentation as an affordable, practical and effective mechanism for long-term documentation of tangible cultural heritage". The purpose of the trial was to create a workflow for 3D imaging suitable for a museum photographic studio, and to measure its cost effectiveness and suitability to the range of objectives held by a national museum.

Methodology

For the purpose of this exercise undertaken at the V&A Museum, the concept of a 3D imaging trial contains several elements. Each of these are separate but necessary to one another to make the idea of 3D modelling of cultural objects both viable and potentially necessary to the CH organisation.

Ideally scholars require images of CH objects for a reason. This may be for publication, teaching, peer to peer research, conservation related activities as well as making the collection better known to the public. Just as for decades the art historian was satisfied with black and white images and indeed had difficulty in both trusting and using colour images when they were first made available to them, then 3D imaging now faces similar questions for the scholar. They currently do not yet fully understand it's potential. One of the purposes of our trial was as an educational exercise. Comparing results of different objects will enable them to better judge the technological potential and then predict when it will be useful and hopefully essential for their work.

Within CH institutions it is the subjective responses which are often the more interesting. There are many parallels to the 2D world. Colour is the most vivid example. The question is often, "is the colour in the object the same as the image?". There are many objective ways to isolate colour matching from using referenced light sources to assigning correct colour profiles on calibrated monitors. However it is the direct comparisons that the scholar will rely upon.

Success will depend on both the viewer of the object, their individual needs and the medium of delivery of the image. Different audiences will have different responses and judgments for success. The museum visitor may just relish the opportunity to see an image in the round, to have an appearance of form and to just see the back of an object; something often denied them in the museum display case. The scholar may be more discriminating and need to be assured of measurements and surface detail. The conservator may want to compare and contrast objects pre and post restoration. All of these different uses are equally valid.

In a large museum it is always best to take advantage of current activity taking place on the collection and use the potential of object moves to gain access to objects. One such opportunity resolves around the re-storage plans for textile collection in the V&A. Up to 100,000 textile objects are to be moved from the South Ken site to more open storage at our Olympia repository. Many of these objects are flat textiles, but many are 3D and fit well within a candidate set of objects. Such things as, shoes, boots, hats, fans, walking sticks and embroidered boxes are a good trial set. For a substantial part of the trial this set of objects provided a case study of; selection of object type, object move, acquisition, objects return and collection of data.

The V&A Photographic Studio is well appointed for imaging in a CH institution, its staff are experienced in all forms of object photography and practised work-flows have been developed for the successful completion of digitisation projects. The Photographic Studio is well equipped with lighting and general photographic accessories so background equipment is substantial. This may not always be the case for a smaller museum. V&A services for art handling and cataloguing were also available from it's own resources.

The trial was undertaken by Carlos Jimenez and Una Knox of the V&A Photographic Studio. They are both photographers by training but have extensive skills in a range of media software. The expertise they bring to the trial is an understanding of the care and consideration necessary with cultural objects, knowledge of lighting objects for reproduction and the skills to use well established and new computer graphic software. They also understand the working arrangements within the museum in the cultural heritage sector, a factor which can influence how work can proceed on an object.

The majority of the scans in the current trial have been undertaken on the Breuckmann Supper Scan HE device. This camera has interchangeable lenses of 180mm 300mm and 800mm focal lengths. Other equipment in the trial has included:

Rigid light cove background
Soft light cove background
Canon DSLR
Flash lights with soft boxes
Manual turntable
Sturdy tripod
Laptop PC computer supplied with the scanner
PC workstation
Dongle for Optocat software

***Fig 1**: Breuckmann SMART SCAN HE*

Training

After receipt of the Smart Scan, Bernd Breukman visited the V&A Photographic Studio to train Carlos Jimenez and Una Knox in use of the scanner. The training took place over two days within the main Photographic Studio space at South Kensington and a couple of objects were scanned during the training exercise. The introductory training that Carlos Jimenez and Una Knox of the V&A Photographic Studio received at the V&A London was sufficient to begin creating 3D models with the Breuckmann Scanner. With basic technical knowledge of the scanner and the accompanying software they were able to understand the working process and to build a portfolio of new 3D models.

It was soon realised that while the speed at which acquiring scans and blending meshes into models steadily improved, using the same parameters in the software and the same adjustments for each acquisition was not suitable for different materials, different surfaces and different objects. The software has many tools which can adjust the parameters effecting different aspects of the acquisition and post-processing of the mesh. In order to gain more experience in the use of these different parameters Carlos and Una undertook further training at Breuckmann Headquarters in Germany.

The advanced training in Meersburg proved to be very useful and enriching. During the training they were able to dissect an existing 3D model which they had created and then make selective improvements to the models using new skills and practical experience.

Within the V&A museum collection the variety of materials is vast, with each object often possessing a unique range of textures. As a result of this diversity, it would be difficult to pre-visualise questions about the best scanning procedure ahead of the physical scanning of objects. The second training session allowed the right questions to be asked as by then they had become familiar with textures previously captured. Knowledge had been gained in what was required in terms of accuracy for the 3D models. They were also able to draw on a substantial understanding of the way the combination of scanner and its software react to materials based on the experience of Breuckmann staff.

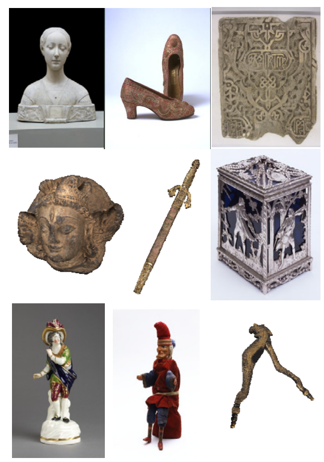

***Fig 2**: Some of the range of objects scanned during this trial*

Working procedure

The first approach towards the scanning process is very similar to that in any form of photography process in a museum environment. There is the need to locate the object, move it, choose the working environment, select the appropriate lighting, and start acquiring images to produce the desired image. There are however also software parameters and manual operations that relate only to the 3D output properties. But mainly the approach we adopted towards 3D was through our understanding and experience of 2D photography.

As in any imaging technique the software and its behaviour are important as to how the object relates to the environment and lighting. These two sides of the process; physical and virtual shaped the behaviour much more than in 2D photography. The result in 2D photography depends on different images that represent an object with a specific purpose; it's appearance, it's texture properties, it's dramatic features etc. The result will be a static image frozen in time and space, non-moveable therefore non-receptive to light changes and dynamism. Meanwhile on the 3D image there is a need to obtain a model with texture as neutral as possible over all the parts of the object. These parts will relate to one another in a much wider sense than with the 2D photographic approach. The object needs to be broken into pieces so the neutral aspect of all single aspects will produce a coherent image. The image should react to light, movement and be humanly recognisable as natural as the real object will be in real life.

The approach to developing this technique has evolved through experience, striving to fail was the approach to understanding how the scanning process works in the best way. We spent a lot of time handling objects at the beginning of our tests. As there is a physical element in the relationship between the way that light, reflections, and quality of region is acquired, there is a procedure that needs to be understood before we achieved the maximum.

Light has definite properties of direction, brightness and exposure that needs to be taken into account. The specific nature of the scanning process has a direct relation with the properties of the object; shape, material and texture. All those parameters mean that the handling of the object and the handling of the scanner have a relationship that affects the success of the scanning process.

Therefore our experience in scanning with Breuckmann's Smart Scan improved not only on the technical side, but also in our physical approach to undertaking the exercise. Selecting the lighting, moving the object in a certain manner particular to that object, changing software parameters and combining different lens resolutions, were all part of our development of this scanning workflow.

Features encountered

Occlusions

Occlusions are a common problem with scanning cultural objects. They occur when parts of the object are difficult to see with the scanner optics. Good visibility of the surface of the object from the light of the scanner projector and from both of the cameras, or at least one of them, is crucial to obtaining a good scan.

The orientation of the object in the capture scene is also important to take into account. The ideal situation is when you are able to manipulate the object. Being able to move it upside down, or change it from vertical to horizontal orientation makes the whole process much easier. However this is not always possible with cultural objects and the limitations of the object can limit the success of the scan. It also has an effect on the time spent scanning. Moving the object can help with access to the occlusions for both the light and the lenses. If this is not possible, then moving the scanner to reach these areas can be attempted but this is a more time consuming activity. A problem with doing a lot of moving around the object is that the lighting conditions can change and will affect the object colour which will vary over different areas. We have performed many scanning acquisitions with small objects supported on a box full of soft rolled paper. This helps us to protect the object as well as being able to support it in different orientations. Not all objects are suitable to be handled in this way and in practice a combination of being able to move the object as well as the camera is the usual way to approach the scanning session.

The depth of field of the different lenses will also affect the data acquired in the process. Out-of-focus areas will not resolve the mesh well. The right balance between all these parameters is not always easy to achieve at the same time, and the shape of the object, the material and the scanner nature can make the scanning process complex.

When it was not possible to acquire the whole object surface and the mesh obtained had holes, they needed to be filled by the software. For all meshes in this trial we used Breuckmann's Optocat or Meshlab. (http://meshlab.sourceforge.net/). There are different ways of filling holes. In Breuckmann's software Optocat, we have the "watertight" filling holes or "filling holes" options. Both of these features will close the holes on the model but with an increase of time needed to finish the post-production of the model. On Meshlab we used the Poisson filter to recreate the surface and to fill all the holes.

Poisson filters will provide different qualities but increase the time of postproduction. The higher the values on the scale the longer the time for processing, and consequently there is an increase in this part of the process.

Both processes are "guessing" algorithms, therefore it should be acknowledged that the representation of those areas is not part of the object itself but all approximate. If the area does not present a complex shape, the "guess" of the process will be more accurate than if it is a complex shape. In this case manual modelling is recommended with the real object or pictures used as a reference to reproduce the features.

In many cases we found that a combination of software filters and visual tests was necessary to get the best results. After the mesh is closed, the texture needed to match the rest of the object where the scan information was recorded. This can be a tedious process and will not always work correctly or as well as desired. If the missing area we are trying to represent is a large one, there will not be any colour information and a possible blank area will appear.

There are no specific filters to correct this issue, although a combination of tricks can be used to fix it. One is to copy an area where there is colour information, attach it with a different orientation to the blank area and then transfer the colour. When the process is finished we delete the wrongly aligned mesh but keep the colour. The best practice is to try to minimise the post-production process by making more scans with smaller amounts of data.

Textile objects

Fig 3: *Textile object*

Scanning this object (Fig 3) illustrated the various problems associated with the 3D imaging of textiles. The object was non-rigid and the material surface was of a 'fuzzy' nature. It was not smooth being made of a woven material with fine hairs extending from its surface. The object is 19th century and is quite worn with thin areas. Visually the surface is perceived as flat but the fine hairs are interpreted as by the scanner fine details. The nature of the material surface also created small highlights which can cause noise in the mesh.

The object is also none-rigid so that there is a danger of distortion of the object between scans. The object was scanned lying down on a pad of supporting material on its back. This was mounted on a turntable so that it could be rotated in front of the scanner between scans. Movement of the object was kept to a minimum. It was only moved three times during the whole process and wherever possible kept within a defined shape. So the major scanning was done with the object in one position and subsequent scans of difficult to access areas scanned once.

The legs presented a particular problem, as they were located beneath the skirt of the puppet. Fortunately they were made of wood so were a rigid part of the object. During the scanning of these, extraneous parts of the textile were virtually removed in processing software before merging the meshes. It was found that there was quite a lot of redundancy in the creation of scans of individual elements of the object.

The tassel on the back of the puppets head is made from individual strands of wool which the scanner was unable to resolve. Hence this part of the object bears no relationship to the actual object. Considerable hole closing was undertaken to complete the surface of the areas of worn textile.

The eyes of the puppet are made of painted glass and therefore transparent and these also did not resolve with the Breuckmann scanner. Though not yet attempted, the eyes would need to be created virtually to complete a full realisation of the object.

Colour

Recording of full colour information with the Breuckmann scanner, and indeed with any of the other colour devices that the V&A has used in recent times, does not allow for accurate recording of ICC colour profiles. When the Photographic Studio is making 2D images, white balance is measured and all recordings of this made in Adobe 1998 RGB colour space. This information is retained within the image file and transferred to any subsequent user of the image. If all colour profiles are both recorded and utilised properly in the imaging workflow then correct colours will be retained in whatever form of output iused. It is not possible to record these ICC profiles in any of the 3D scanners we have used. It is likely that the colour space used by the internal texture capture devices is in sRGB, the smallest of the available colour spaces and the one least suitable for CH objects. Recording texture images with high-end digital cameras and placing these onto completed meshes improves the texture result but does add considerably to the post-production time.

Lighting the scene for scanning

Due to the nature of the scanning technique used, with the need to make a large number of scans around the object, we developed a method of lighting the scene to reduce as much as possible the change of colour and shadow created on the object. Normal practice was to mount the object onto a small turntable and rotate the object between scans with the scanner and lights kept in a fixed position. The turntable was itself set within a rigid fibreglass cove background painted a neutral white colour. This was illuminated with flash soft boxes. In this way the lighting on the subject was even, ‘wrapped around’ the object and reduced the shadows considerably. The intention was to make the lighting on the object exactly the same for each view of the rotated object.

Shininess

Fig 4: *Silver and glass object*

This silver box is made from a combination of polished silver and translucent glass. It proved to be an impossible object to scan with the Breuckmann scanner. The reflective surface produced a lot of noise resulting from areas of extreme highlight. These manifest as large spikes in the mesh. The glass was transparent to the scanner projector light so did not produce any useful data.

The exercise was abandoned before post-production as there was insufficient data to make a reasonable model.

Noisy objects

The history of 3D scanning of physical objects, particularly in Europe, has been dominated by two schools of cultural heritage, archaeology and classical and neo-classical objects mainly from the Renaissance. Due to their nature these types of objects have mainly coherent surfaces. The Collection at the V&A is large and is comprised of many objects throughout the whole range of manufactured objects. Though our trials have not been exhaustive over all of the types of object that we have in the collection, we have observed that many objects have the concept of ‘noise’ within their material structure. We feel that this is distinct from surface texture. We scanned a shoe made from a textile fabric. It was composed of a mesh of threads in a warp and weft pattern. The textile threads were composed of microscopic hairs. So at a macro level the object surface was rough and hairy. It was such a fine level that the scanner light had difficulty in resolving the fine detail. From this we developed the concept of a ‘noisy’ object, one where the actual surface detail would affect the performance of the scanner.

Each object then in our opinion can exhibit several features which will affect the efficiency of the scan:

Texture (roughness)
Reflectance /diffusion
Occlusion.
Rigidity
Transparency/translucency
Noisiness
Size
Colour

Operating costs

The V&A Photographic Studio is a wholly funded department of the V&A Museum. It operates with full-time employed staff in purpose built studios within the museum buildings. Hence the cost of effort for 3D scanning comprises of the following elements:

Staff cost
Capital equipment cost and depreciation

To run a full-time scanning campaign we would consider two photographers necessary to run this effectively.

Equipment cost based on the Breuckmann scanner is approximately €80k. This is assumed to depreciate to zero over four years. Other institutions may or may not already have support equipment such as lights, backgrounds in place. If not these would cost in the range o €17,500.

Hence start-up cost would be a total of staff, at mid-point on the scale, and equipment would be approximately €150,000. Second and subsequent year costs would be approximately €53,000.

If a normal working year is considered to be 250 days per year, then it would be reasonable to expect to make at least around 150 models per year. With experience and improvements in workflow this could be expected to increase to maybe 250 models per year. This does of course depend on the object type. On average then, over a four year period, could be expected to cost around €300 per model.

Conclusions

The whole operation of making images of any cultural object in a museum or gallery context is similar regardless of the type of object worked on. The following describes the workflow for the different aspects of the process. They are in sequence:

Initial response to an imaging request
Assessment of the object
Decision on technological approach
Access and movement
Imaging setup
Capture process
Storage
Search and find

Undertaking this trial presents the V&A Photographic Studio with the development of a workable method for creating a new multi-media product for the Museum. The experience gained from undertaking training and understanding the range of cultural heritage objects that can be scanned successfully has meant that a realistic 3D digitisation exercise can now be undertaken. This gives us encouragement to be able to offer this as a museum service. The presentation of 3D models to staff in the museum has created interest in the medium and has allowed them to consider how it can assist them in their work or be able to present the collection to the visitor in new interesting ways.

During the course of this trial the V&A has realised that there are both differences and similarities between 2D and 3D workflow. The similarities though can form the basis of an effective production cycle. With this in mind the V&A Photographic Studio has taken advantage of its experience of photographing the cultural object in a public service museum environment and applied it to 3D. Though our public service element is particular to a well-resourced National Museum, the principles can be applied to anywhere there exists a competent professionally trained photographic service. The elements of workflow, which are comparable, are;

Initial response to an imaging request
Assessment of the object
Access and movement
Imaging setup

All of these elements, though they may differ from CH institution to CH institution, will be the same regardless of the imaging task. Indeed they are largely the same for any activity taking place on the CH object.

For 3D imaging however the differences can be shown as;

Decision on technological approach
Capture process
Storage

The issue of 'fit for purpose' scanning is one, which is still relevant for 3D, however we have largely followed our general 2D principle of 'scan once, use many times'. In our 2D workflow we make images that will be reproduced at least as A3 at 300 ppi. In this way we cater for almost every use that the Museum may need for its images. It is with this in mind that we scanned objects as efficiently as possible. So this dictated our technological approach. This was determined early on in our trial and continued for its whole period.

It is these areas where training in the 3D medium is needed and where extra attention to IT infrastructure particularly for storage needs to be assessed before a campaign is started. At the V&A the time needed to become fully comfortable with the technological approach has taken at least six months. Though acquisition took place well before this, it took this period of time to become fully comfortable with the way that CH objects are recorded in 3D and how the many parametric features of 3D software can effect the visualisation of the final model. The V&A were fortunate to receive training from the supplier of the structured light scanning equipment used, but experience and observance of effects of actually doing the work is necessary.

It was the intention of the V&A to gather as much experience as possible represented by the wide variety of objects housed in the museum. There are still many different objects which will present new challenges, for example we have not yet scanned either furniture or dressed mannequins, but the range scanned has indicated which objects can be considered, difficult, challenging or impossible.

Scanning in 3D is a lengthier process than 2D imaging. This has an effect on the use of workshop spaces. To fully complete a task requires that space is occupied for at least 24 or 48 hours. For 2D the turn-round time for a studio can be within 1 or 2 hours. This has an effect on the efficient use of space in the workspace suite. For the manager of 2D production the cycle is rapid, for the 3D manager longer. Hence to combine the two disciplines can be difficult. With this is mind to undertake a substantial 3D digitisation campaign would require its own dedicated workspace.

Imaging in 3D in terms of the scene is substantially different to that in 2D. In 2D imaging the background in the image is important to the perception of that object represented in the scene. A poorly composed background can make a image of a CH object itself look poor. To achieve a well composed background requires skill in lighting, and space to organise the lighting setup outside of the scene. In 3D modelling the objective is just to acquire an image of the object and to leave the construction of a background visualisation to post-production. This means that less care can be taken with the background and lighting rig during the acquisition phase. If wires or lighting stands trail into the scene or the background is uneven and poorly lit it is largely irrelevant. During the trial we often had to work in museum stores of galleries. These spaces are less versatile than Photographic Studio spaces, but due to the nature of the acquisition did not compromise the imaging.

It was a surprising consequence of undertaking 3D scanning to realise that there is a fundamental difference to 2D imaging. The 3D acquisition process is a multi-stepped task creating no single 3D file, because unlike 2D you are working in the round, rather than on a single face of an object. 3D acquisition comprises of making multiple exposures and compositing these into a single whole. The multiplicity of files made in this process is considerable and varies with the different proprietary devices used. All of them however make large directories of folders and sub-folders of meshes, images and other production files. We have measured that there can be a ratio of 27:1 for 3D production files against the final model, where of course for 2D imaging it is 1:1. This raises the issue for digital preservation as to whether you retain all of this production data or just the final 3D model. Even with our limited experience we have realised that you can re-process the production data to make refined models, and that there can be other operators who may take your data and made different iterations of the object. This is similar to Ansel Adams philosophy of the black and white negative where he considered it similar to a musical score which can be re-interpreted by different performers.

For the IT department this is a considerable issue to take into account. When a 30Mb 3D model is made from 4.7 Gb of data, then in a large scanning campaign the numbers soon build up into terabytes of storage. This has the consequence for digital preservation of format redundancy and migration and substantial back-ups. As much 3D scanning is undertaken on proprietary devices, file formats vary and sometimes only work on single software platforms. So it may also be necessary to keep software versions, which of course have the consequence of changing operating system platforms.

Author Biography

James Stevenson is the Photographic Manager of the Victoria and Albert Museum. He has responsibility for the management of all image and multimedia creation within the museum. James Stevenson was previously at the National Maritime Museum, Greenwich as Chief Photographer. He has been employed as a photographer since 1974.

Carlos Jimenez, graduated in Fine Arts and holds a speciality in Arts of the Image with distinction mark. He has been the main 3D scanner operator at the Victoria and Albert Museum where he also have direct filming and photography sessions.

Peter Kelleher has been the Motion Media Manager, Film Director, Photographer, in the Photographic Studio at the V&A Museum since 2001.

Una Knox received a BA in Photography from Emily Carr University, Canada and MFA from Goldsmiths College, University or London. Since then, she has worked in cultural heritage imaging as a photographer in museums and galleries in Vancouver, Canada, New York, NY and most recently at the Victoria and Albert Museum, London as part of the 3D image research team.