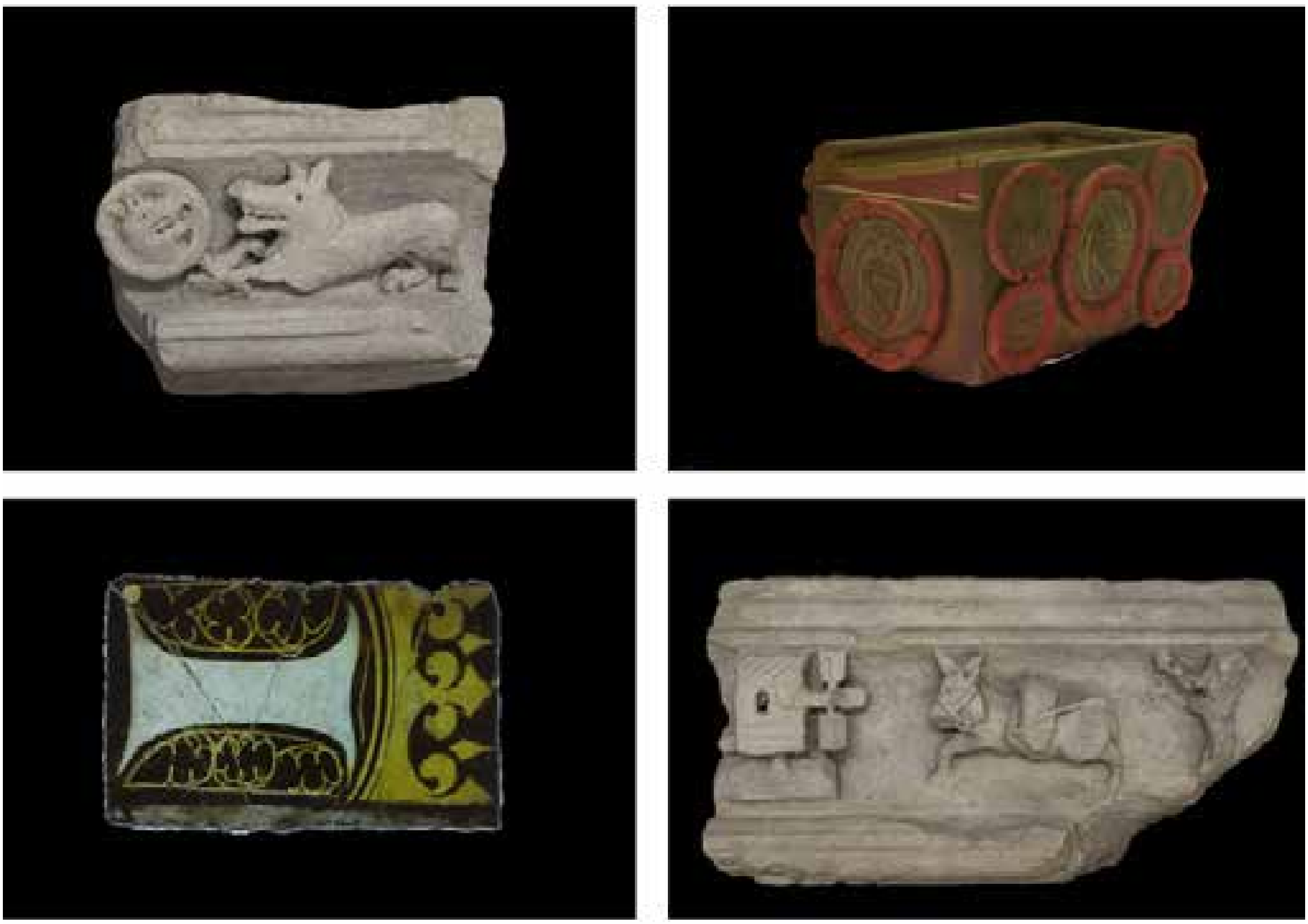
Historic England

Geospatial Imaging

Structure-from-Motion recording of artefacts from Helmsley Archaeological Store, held by English Heritage Trust

Li Sou

Discovery, Innovation and Science in the Historic Environment



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SUMMARY

The reserve collection of artefacts of English Heritage's North Territory is housed in the Archaeological Store in Helmsley, North Yorkshire. It contains a substantial amount of medieval stonework from nearby Rievaulx Abbey and Fountains Abbey. Currently all artefacts are documented to a basic level of site, location in store, simple object name and material. The majority have higher levels of information which includes a description, measurements, context (where known) and record photography. Record photography is typically one to several views with a scale, and all artefacts are recorded on the heritage object management database, some with linked digital images, whilst others have more detailed paper based records in catalogues. Some basic stereo photogrammetric recording is undertaken for stonework, however little has been processed (Harrison 2016, pers. comm.).

A new visitor centre for Rievaulx Abbey was completed in spring 2016, resulting in the permanent move of several objects associated with the site from the stores to new displays. With this development, the curatorial team at Helmsley decided to investigate whether Structure-from-Motion (SFM) photogrammetry could be a suitable means of recording artefactual data to meet their different needs for imagery. The CIfA placement holder in Geospatial Investigation Techniques at Historic England was tasked with creating 3D data outputs from images taken of different Rievaulx artefacts, for English Heritage's curatorial team to assess for their suitability for record keeping, artefact analyses, conservation records, online and print publication, education, and public displays.

CONTRIBUTORS

The photography was undertaken by Li Sou, the CIfA placement holder with Historic England's Geospatial Imaging team, with assistance from Sofia Antonopoulou, Digital Documentation Intern at Historic Environment Scotland, whilst on an exchange visit. Li Sou, with the assistance of Jon Bedford, of Historic England's Imaging team, processed the digital imagery for Structure-from-Motion photogrammetry. Li Sou conducted the data analyses of the project, with additional comments from Paul Bryan. Unless stated otherwise, the images used in the text were produced by the author.

ACKNOWLEDGEMENTS

The author would like to thank Susan Harrison, Curator of the Helmsley Archaeological Store, for her permission and help in arranging the photography of the artefacts.

ARCHIVE LOCATION

The report has been deposited at the Historic England Archive, The Engine House, Fire Fly Avenue, Swindon. The processed photography is held with the Historic England Archive under survey number 16/109/1P.

DATE OF SURVEY

On site photography was taken between 4th and 5th April 2016, with a further visit to the store on 28th June 2016 for additional photography.

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CONTENTS

PART 1: THE PROJECT 1

INTRODUCTION 1

BACKGROUND 1

PART 2: VISUALISATION TECHNIQUES 3

METHODOLOGY 3

PART 3: RESULTS 7

EVALUATION 7

3D MODELS 8

PART 4: DISCUSSION 25

USING SUITABLE LENSES FOR ARTEFACT PHOTOGRAPHIC RECORDING 25

PLACEMENT OF ARTEFACTS AS AN AID TO PHOTOGRAPHIC RECORDING 25

LIGHTING 26

RECORDING STUDIO SPACE 27

RETURN VISIT 28

COMMENTS ON SUCCESSFUL SFM PROCESSING 28

PART 5: CONCLUSION 29

BIBLIOGRAPHY 30

PART 1: THE PROJECT

INTRODUCTION

Between 4th and 5th April, and on 28th June 2016, photography for Structure-from-Motion (SFM) photogrammetry of artefacts held in the Helmsley Archaeological Store was undertaken by the CIfA Specialist Training Placement in Geospatial Investigation Techniques at Historic England, with help from the Digital Documentation Intern at Historic Environment Scotland, in order to generate 3D models of particular artefacts intended to be placed on permanent display in the new visitor centre at Rievaulx Abbey. This report documents the methodology and results of the 3D outputs generated from the photographs taken on site, in order to recognise the potential benefits and issues of conducting such recording within the store.

The project was undertaken as part of the placement holder's training programme with the Geospatial Imaging team at Historic England, and was conducted as a means of determining whether SFM photogrammetry is a feasible and useful method of maintaining a digital record of artefacts within the Helmsley Store collection, for a range of purposes required by the curatorial team. As such, a selection of 12 artefacts of varying size, shapes and materials were selected for recording, in order to determine the possible limitations of SFM processing can have on the type of artefacts that can be successfully recorded in this way. Additionally, all photography was undertaken under regular lighting conditions and work set ups used by the curatorial team, as a means of analysing the quality of 3D data that can be generated by the team with equipment readily available to them.

After the initial survey, a return visit was made to record a further artefact: a balsa wood box and its lid dating to the 19th century, decorated with wax stamps taken from medieval seals originating from Fountains Abbey.

Once generated, the 3D data and models were assessed for their quality, before the data was sent to the English Heritage curatorial team at Helmsley for their own assessment of their usability and applicability to their everyday workflows.

BACKGROUND

The English Heritage curatorial team at Helmsley currently record the reserve collection of archaeological artefacts from North territory guardianship sites to a basic level of site, location in store, simple object name and material. The majority have higher levels of information which includes a description, measurements, context where known and record photography. Record photography is typically one to several views with a scale. All are recorded on the heritage object management database, some with linked digital images, whilst others have more detailed paper based records in catalogues. Some basic stereo photogrammetric recording is undertaken for stonework but little is processed.

Considering these factors, it was proposed that SFM photogrammetry be trialled as a method of recording artefactual 3D data by the Geospatial Imaging team, Historic

England, to determine whether the data generated could be applied in a variety of useful ways to the curatorial team at Helmsley.

It was proposed that SFM could offer potential benefits to the way that artefacts are recorded, including the production of accurate digital 3D models that can be viewed at all angles, and the potential to view models in widely accessible formats such as 3D PDFs. With the movement of many artefacts from Helmsley to the new visitor exhibition for Rievaulx Abbey in spring 2016, the Helmsley curatorial team were interested in different ways to organise and present the selected artefacts to be displayed.

Main concerns for the curators included the quality of the 3D imagery generated, accessibility of the recording methodology and software, and applicability of the techniques for; record keeping, artefact analyses, conservation records, online and print publication, education, and public displays. As such, a programme of photographic recording of a selection of artefacts took place, to produce SFM photogrammetric models, to determine if the outputs were suitable for such uses.

PART 2: VISUALISATION TECHNIQUES

METHODOLOGY

In order to produce a detailed SFM photogrammetric model, overlapping digital photography of all areas of an artefact intended to be recorded is necessary. The initial phase of recording artefacts from Rievaulx took place between 4th and 5th April 2016, using a Canon 5D MKII DSLR with a prime fixed 28mm wide angle lens, mounted on a tripod and set to aperture priority mode.

A series of overlapping shots was taken for each object, stored in RAW mode. A maximum depth of field was desired for all shots, to maintain sharpness and to ensure all areas of the artefacts were in focus, to better process the images in Agisoft Photoscan, so the aperture priority setting was used. Grey scale and colour scale cards were placed beside each object for post-processing colour adjustment in Adobe Camera Raw, and scale bars arranged for marker placement in Photoscan, to both scale the models produced and to aid in point alignment. After colour calibration, all RAW photos were converted to TIFF format, with metadata added, before processing in Photoscan.

Medieval carved stonework

The stone artefacts were moved from their respective shelves on their loading pallets into the corridor of the store warehouse. It was possible to rotate some smaller fragments with help from the store's curator, however due to their substantial weight, it was not possible to separate clusters of heavier stonework onto different pallets for photography, nor raise their height or physically rotate them. Photography was taken to achieve maximum coverage of the stone artefacts (figure 1), but due to the low height of the artefacts and limited space in the warehouse corridor, acquiring sufficient imagery of their sides was difficult (figure 2).

Small finds from Rievaulx Abbey

Small finds were photographed using the same set up as the recording of the Rievaulx stonework, however the recording took place on a desk within the Helmsley store office (figure 3). The desk was situated at the end of the office, conjoined by two further desks used by members of English Heritage staff and volunteers. A layer of bubble wrap was placed on the desk surface to protect the small artefacts when they were arranged on the desk, and artefacts were only rotated and moved by the English Heritage curator.

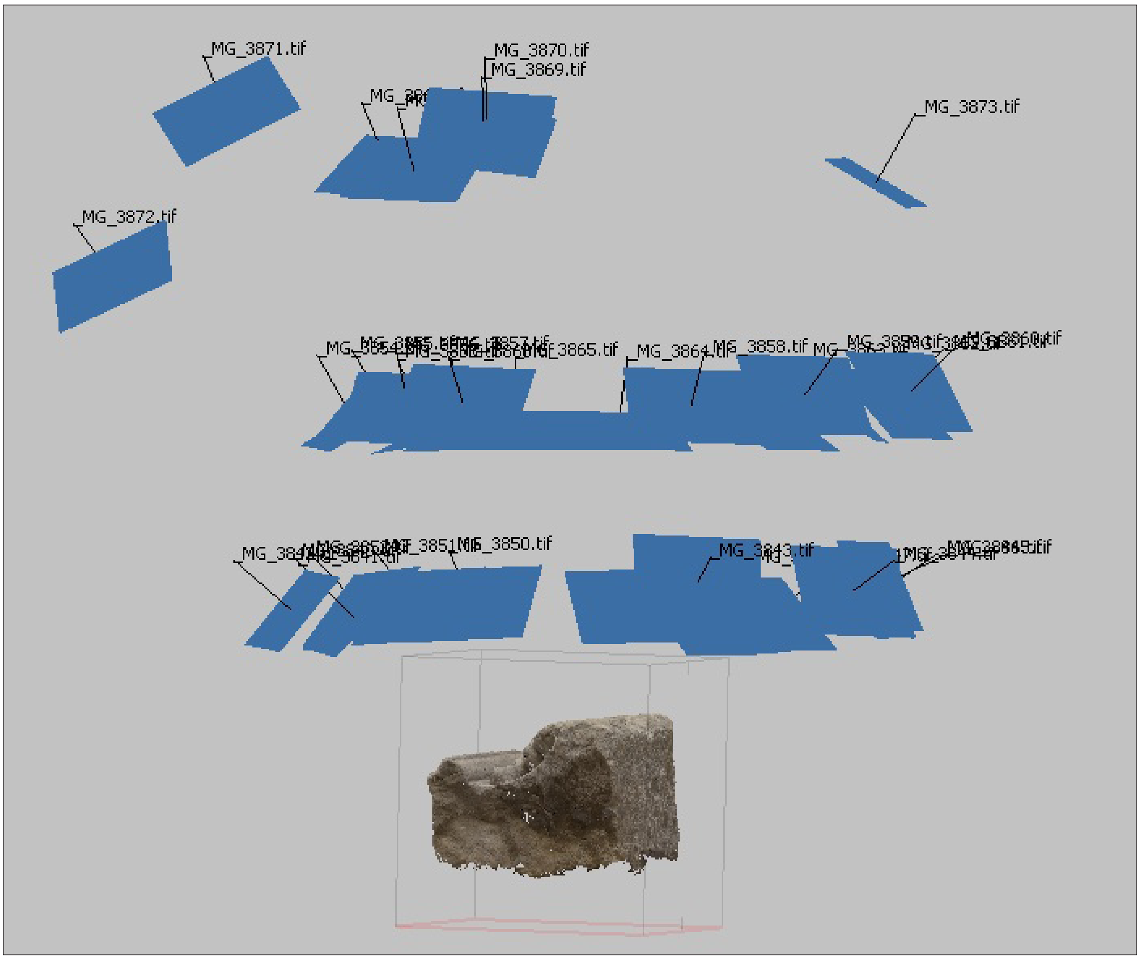

Figure 1: Screenshot from Agisoft Photoscan showing the location where each photograph was taken (blue rectangles). This view is taken from the side of the object in the 3D view port. Two circuits of photography were taken around the artefact (at the bottom) at different heights for more complete coverage, with additional shots for further details.

Photography of an artefact from Fountains Abbey

After the initial sets of data were processed using SFM photogrammetry, it was evident in the results that the wide angle lens used to take the photographs of small finds was not ideally suitable, as it was not possible for the artefacts to fill the frames of the shots. Jon Bedford, Senior Geospatial Imaging Analyst at Historic England, recommended a zoom lens be used to focus on a small object, with the camera mounted to a horizontal bar to acquire closer range, in focus shots of the artefacts from above. A zoom lens was not available for the Canon camera, so the later sets of photos were taken using a Nikon D3X, with a 28mm zoom lens set to a fixed focal length for the duration of the artefact photography (figure 4).

The zoom level was fixed, however due to the weight of the lens on the horizontal bar, this slipped in the second and third batch of photos. A plain white background was set beneath and around the artefact, and for side angle shots, the artefact was raised on a box to ensure the camera was positioned directly opposite the faces of the artefact, and not from an oblique angle that reduces the point coverage with further distance from the camera.

Figure 2: Image taken from Canon 5D MKII with prime 28mm wide angle lens. Note the tight arrangement of the artefacts placed close together, the low height of the artefacts and the narrow space between the pallet and shelving. The wide angle lens has recorded extraneous areas of the surroundings which produce unnecessary data in SFM processing.

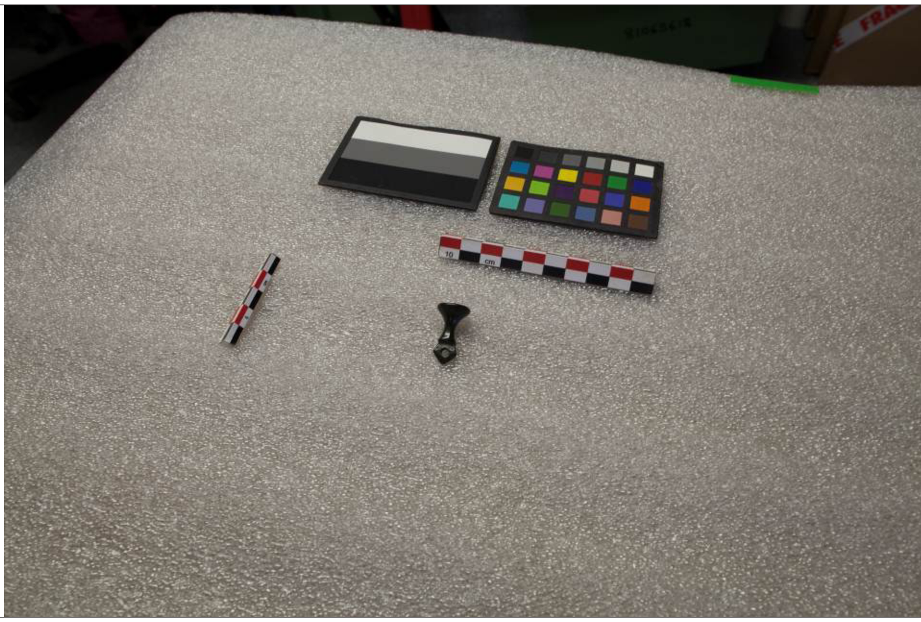

Figure 3: Photography set up of a small seal from Rievaulx Abbey, placed on the recording table. Note the irregular surface of the bubble wrap.

Photoscan processing

All artefact photography was imported into Photoscan for processing. Scale bars were added as markers where they featured in photographs and a set workflow was followed for each part of the SFM processing. Firstly photos were aligned using the high accuracy setting, with masking applied to non-relevant areas of each photo which were not processed. The default key point limit of 40,000 and tie point limit of

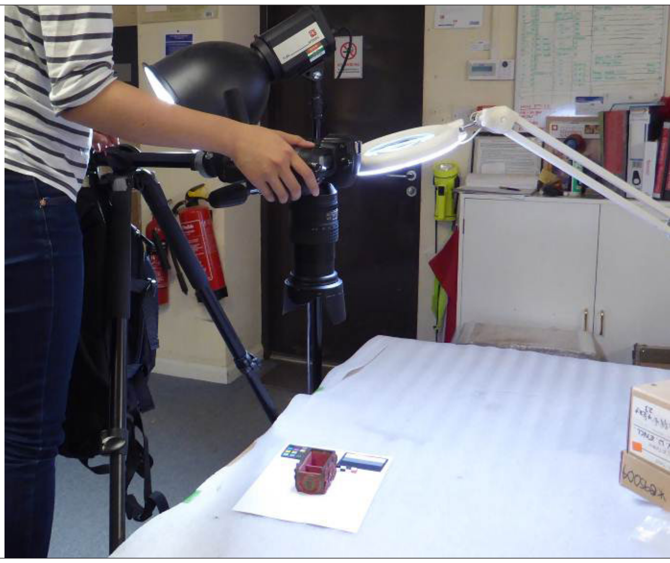

Figure 4: The second set up for photography, using a horizontal bar on the tripod for overhead photography of the artefact and an LED lamp for lighting the artefact. The camera operator had to stand on a stool to see the artefact through the camera viewfinder.

1,000 were used. Following this, a dense point cloud was generated. The dense cloud quality was set to high, with low depth filtering to capture the intricate areas of the artefacts.

Meshes were created using the dense cloud as the data source, with an arbitrary surface type and high face count to capture details of the artefacts. As this exercise was conducted to evaluate the data quality of the photography taken, interpolation of the mesh was disabled, preventing the programme from estimating how areas void of points should be filled, thus leaving these areas blank and empty.

Lastly, textures were built to wrap over the mesh. The default Photoscan settings were used, with mapping mode set to generic and blending mode to mosaic, with one texture image used for an entire mesh. Colour correction was enabled to give the 3D models a more balanced colour that would be closer to the artefacts' appearance in reality.

After the photogrammetric models were completed, they were saved and decimated versions created, where the mesh polygon count was reduced, to reduce the file size of the models for practicality of use. These less detailed versions of the models were exported as U3D files, for additional editing in Adobe Acrobat, where they were finally made into 3D PDFs, which are viewable in most PDF viewing programmes. As the Helmsley office does not have specialist SFM processing or viewing software, it was felt that 3D PDFs were the most appropriate and accessible format of generating and viewing 3D models for the Archaeological store.

PART 3: RESULTS

EVALUATION

After SFM processing, nine 3D models of artefacts were successfully generated. Photography was taken of 13 unique artefacts in total. Certain artefacts were recorded in separate Photoscan projects due to their fragmentary nature, and six did not process correctly, so no 3D PDF was generated of these artefacts (table 1). It was originally anticipated to digitally model fragments of artefacts together in 3D meshing software, however this was not possible due to time constraints on the project. The Photoscan projects remain archived with the Geospatial Imaging team, Historic England, so it would be possible to do this in future, should such visualisation be required.

Artefact (Photoscan project)	Artefact no.	Provenance	3D PDF produced?
Box decorated with seals from Fountains Abbey	671570	Fountains Abbey	Yes
Box lid decorated with seals from Fountains Abbey	671570	Fountains Abbey	Yes
Carved label stop	81300250	Rievaulx Abbey	Yes
Fragment of a rood screen	81065603.2	Rievaulx Abbey	Yes
Frieze of mules led by a man, left section	81065604	Rievaulx Abbey	Yes
Frieze of mules led by a man, right section	81065604	Rievaulx Abbey	Yes
Frieze of a tiger and hunters stealing cub, right section	81065605	Rievaulx Abbey	Yes
Frieze of a tiger and hunters stealing cub, left section	81065605	Rievaulx Abbey	Yes
Medieval jug	88284658	Rievaulx Abbey	Yes
Stained glass panel	960132.2	Rievaulx Abbey	Yes
Copper alloy seal	85000882	Rievaulx Abbey	No
Floor tile	81065608.53	Rievaulx Abbey	No
Fragment of painted wall plaster	88287791.8	Rievaulx Abbey	No
Mosaic tile	88287571	Rievaulx Abbey	No
Pendant with Edward III's badge	81065643	Rievaulx Abbey	No
Scourge	81065661	Rievaulx Abbey	No

Table 1: List of the artefacts recorded during the survey. The left column lists the artefacts as separate Photoscan files, and the second column indicates where different parts of the same artefacts were recorded separately.

The 3D PDFs are kept with Geospatial Imaging team, Historic England and copies have also been sent to the Helmsley Archaeological Store Curator. Here, screenshots will be used to discuss the resulting models successfully produced from SFM. A discussion will follow that highlights the problems faced and explains why other photographed objects did not process successfully, with suggestions and advice given for any such future recording.

3D MODELS

Box decorated with seals from Fountains Abbey (Lab no. 671570)

Two separate 3D models were produced of a balsa wood box and lid decorated with wax seal impressions from five different seals found at Fountains Abbey (figure 5). The texture gives the model a realistic look and reveals the seal impressions with much clarity. However, observing the actual 3D mesh generated, it is clear that the 3D model is not as highly defined, particularly around the edges of the wax impressions, which are quite uneven (figure 6). It could be suggested that this appearance may have been affected by the shiny, reflective and texturally indifferent appearance of the painted red wax. SFM photogrammetry struggles to work correctly on surfaces that lack variance in texture, and those which are reflective.

Figure 5: Side view of the 3D model.

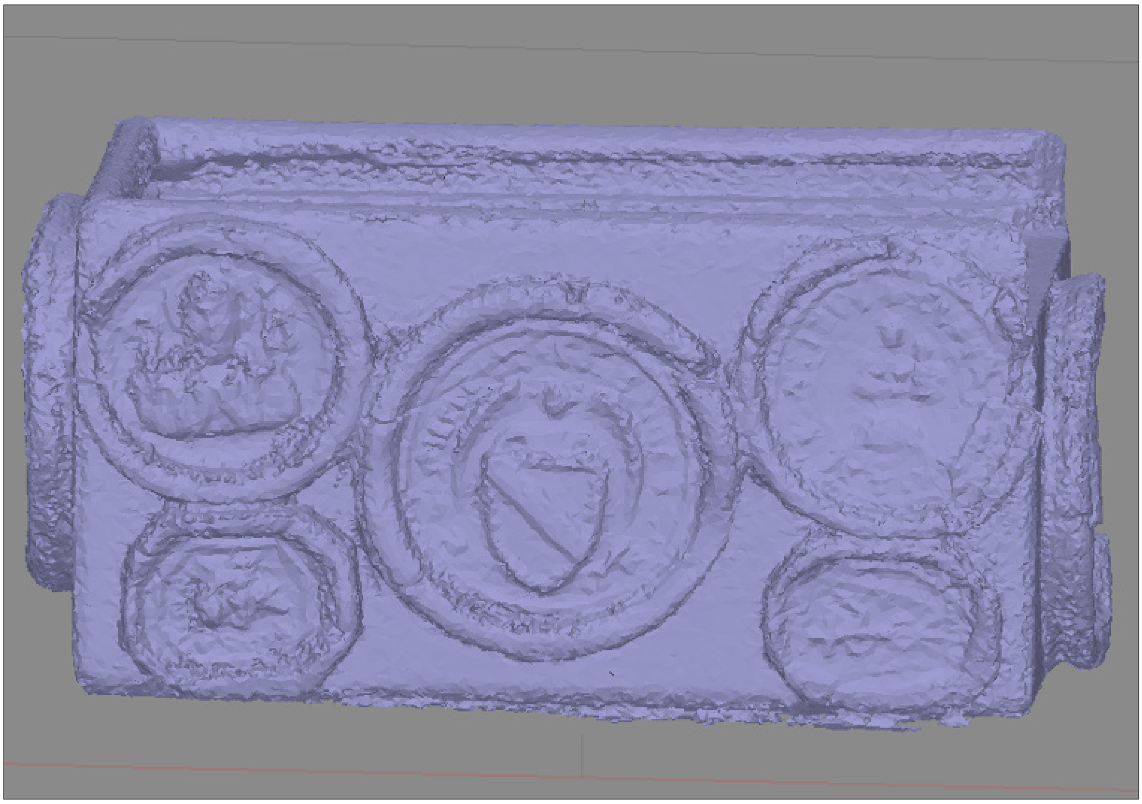

Figure 6: Mesh of the box without the texture.

The model is composed of separately processed chunks, which have been merged together in Photoscan. Unfortunately, the amount of imagery that covered the interior of the box was insufficient for Photoscan to successfully align these areas, resulting in the interior of the box lacking data and appearing blank (figure 7).

The base of the box had similar processing issues, leaving gaps in the model where SFM failed to align points from the photographs (figure 8).

In hindsight, taking extra photographs from different angles, and ensuring a scale bar was securely placed beside the artefact for all shots would have aided in the SFM alignment process. Unfortunately, due to a lack of space on the improvised raised platform used to take photography from, the scale bars had to be taken off and replaced in the next batch of photos, leading to inconsistency. This caused confusion in the SFM processing, so the scale bar was masked altogether and not used.

The Helmsley Archaeological Store holds one of the original seals from which the impressions were made; a seal of court (lab no. 671103.2). Unfortunately, due to time constraints, it was not possible to record the seal in the duration of this project, but a comparison of the seal and the impression created as 3D models would make for a very interesting analysis of their decorations, materials and use wear over time.

Figure 7: The 3D model is composed of several "chunks" that have been merged together, as the top and base of the box had to be photographed at separate times. The interior is missing in the mesh.

Figure 8: Looking onto the base of the box on the 3D PDF. Note how there are holes in areas where alignment did not occur, and how some of the edges do not fit together neatly.

Box lid decorated with seals from Fountains Abbey (Lab no. 671570)

The lid of the balsa wood box was recorded as a separate Photoscan project (figure 9). Initially, it was intended that the two meshes would be fitted together digitally; however this was not completed due to time constraints.

Figure 9: Front view of the 3D model, seal box lid.

It is clear that SFM failed to process the sides of the object accurately. The object was very thin (approximately 5mm thickness) and as such, lay very close to the raised platform, which was covered in a sheet of plain white paper to facilitate quick masking. However, due to the shallow depth, the sides of the lid were very difficult to photograph using the set up described above, and insufficient overlap meant that the sides were not reconstructed properly (figure 10).

Figure 10: Side view of the 3D model. Here, the inaccurate representation of the edges of the lid is clearly visible. The sides had to be cropped from the mesh as they blended into the surface that the artefact rested on.

Carved label stop from Rievaulx Abbey (Lab no. 81300250)

The carved label stop, the lower end of a drip mould, features a human-like grotesque (figure 11). Overall, the SFM photogrammetry processing was highly successful, as the stonework was centrally placed onto an empty stacking pallet for photography, enabling full coverage of the exposed faces to be photographed. Additionally, the range of textures on the stone made photo alignment highly successful (figure 12). The only areas missing information are the underside of the nose and parts of the leaf carvings between the face's chin. This was due to the label stop being placed very close to the ground, so it was not possible to photograph these areas without raising the stonework higher from the pallet.

Figure 11: Screenshot of the label stop model.

The underside of the label stop was not recorded as the label stop was not turned, due to its weight, however, if further imagery of the base was taken, it would be possible to merge two meshes together to produce a complete 360° 3D model.

Figure 12: Side of the label stop. Note the varied texture of the surface.

Fragment of rood screen from Rievaulx Abbey (Lab no. 81065603.2)

The fragment of a rood screen was challenging to model as the protruding details are closely arranged, making comprehensive photographic coverage difficult using only the wide angle lens that was accessible at the time of survey. Whilst the outer details have been successfully recorded, the interior sides of the decoration are missing (seen as areas of black on figure 13 and 14). To produce a more detailed model, it is suggested that a macro-lens is used for photography, and for the rood screen to be raised to a level to ensure detailed overlapping photography of its carvings can be taken from different angles and locations. To produce a complete 360° 3D model, it must be turned upside down, and temporary markers may need to be placed on the stonework surface to allow the separate meshes to be merged together and aligned correctly.

Figure 13: Fragment of a rood screen as a 3D model.

Figure 14: Side view of the rood screen. Parts of the details did not model properly due to lack of overlapping coverage in photography.

Frieze of mules led by a man, from Rievaulx Abbey (Lab no. 81065604)

The frieze of two men leading mules towards a mill is currently in two parts that were originally joined. As they are currently separate fragments, two separate models were produced of the frieze (figure 15). They were originally part of a series of comices located in the Infirmary Hall, and dates to c. AD 1400 (English Heritage 2016).

Unfortunately, the fragments were tightly arranged on a storage pallet, and it was not possible to move or separate the stonework onto separate areas for photography. As a result, there was insufficient coverage of the sides of the frieze in photography, leading to the sides lacking a substantial amount of data (figure 16).

Figure 15: (Front view) The two fragments of the frieze as 3D models, placed side by side. From the front view, the level of detail is good, with only the small window of the windmill and the pack of the left-side mule missing information.

Figure 15: (Back view) The two fragments of the frieze as 3D models, placed side by side. From the front view, the level of detail is good, with only the small window of the windmill and the pack of the left-side mule missing information.

Figure 16: Side views of the 3D models missing data, including the mule's leg and man's back.

Figure 16: Side views of the 3D models missing data, including the mule's leg and man's back.

Frieze of a tiger and hunters stealing a cub, Rievaulx Abbey (Lab no. 81065605)

The frieze of two hunters stealing a tiger cub from its mother is currently in two parts that were originally joined (figure 17). As with the frieze of the mule, these were processed separately.

As the sides of the frieze were more exposed than the one above, more of these edges were modelled, however areas are still noticeably missing (figure 18). Despite this, the right side of the frieze was recorded very well, with the deep relief of the carving successfully recorded.

Figure 17: (Left) Front view of two parts of a frieze depicting two hunters stealing a tiger cub (small bundle on the bottom right of the left side fragment).

Figure 17: (Right) The tiger on the right side gives chase but is distracted by a mirror the hunters leave behind, which she mistakes for her cub (Harrison 2016).

Figure 18: (Left) missing areas that were not modelled in SFM shown in black.

Figure 18: (Right) the deep relief of the tiger has been recorded in detail, particularly the protruding back leg.

Medieval jug from Rievaulx Abbey (Lab no. 88284658)

Although the glazed medieval jug successfully processed, the completed 3D model has several problems. The reflective surface of the jug has caused misalignment of points from the photos, leaving holes in some areas and incorrect placement of points on the surface of the jug (figure 19). This highlights the problem that highly reflective and shiny surfaces can cause to photo alignment in SFM, and it is suggested that artefacts with such qualities are not ideal for this type of modelling and recording.

Figure 19: Side view of the 3D model. The rim of the jug is missing and the handle has not been modelled correctly.

Stained glass from Rievaulx Abbey (Lab no. 88287571)

An experiment took place to determine whether it was possible to record medieval stained glass patterns using SFM photogrammetry, as glass objects are known to be problematic for this technique as its transparency can cause inaccurate location measurements of points. The fragment of stained glass from Rievaulx Abbey consists of three conserved pieces that have been refitted together. It was lit from beneath to reveal the detailed patterns on the glass, using tissue paper to diffuse the light from a LED light panel (figure 20). The glass was then photographed using the same methodology as all other artefacts, and SFM processed.

Figure 20: Set up for lighting and photographing medieval stained glass. Note the distant area of the image is out of focus due to the type of lens used and the angle of the photo taken.

Upon processing the glass using SFM photogrammetry, a complete 3D model was successfully produced (figure 21). However, some inaccuracies were noted in the point cloud and mesh produced, particularly in areas of clear, transparent glass (see figure 22). In this instance, it appears that the SFM processing has interpreted the surface below the stained glass to be the actual surface of the glass itself. It is suspected that the transparency of the glass in such areas caused this confusion.

Figure 21: Overhead view of the 3D model of stained glass.

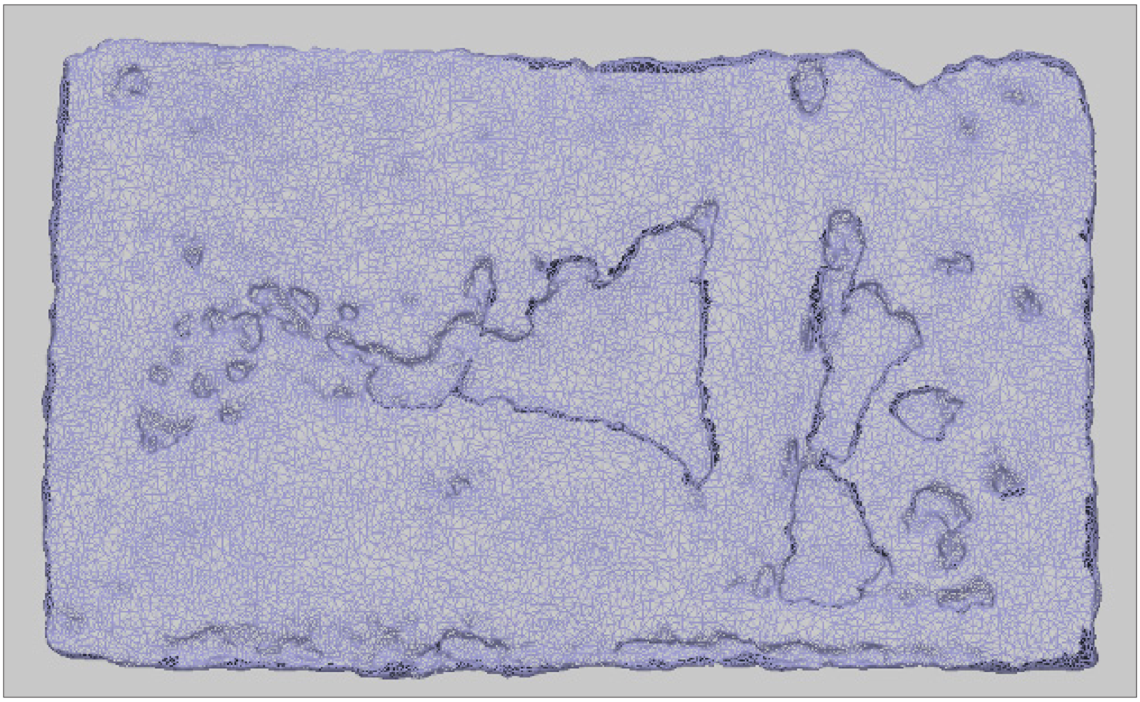

Figure 22: Mesh of the 3D model without texture data. The incorrect depth of the surface is obvious to see in this view.

PART 4: DISCUSSION

Throughout the SFM processing of the imagery captured during the survey, several issues were revealed from the recording stage that led to implications for successful modelling. As such, each of these factors is described below, alongside the methods used during the survey to help alleviate the problems. Suggestions as to how these issues can be prevented or resolved in future surveys are then provided. Additionally, an overview of the successfully modelled artefacts will suggest reasons for SFM working in their case.

USING SUITABLE LENSES FOR ARTEFACT PHOTOGRAPHIC RECORDING

The lens available for use was a prime fixed wide angle 24mm lens, which meant that it was very difficult to frame the artefacts within each shot for the recording of small artefacts. The placement of the larger stone artefacts on low palettes, closely alongside others, meant that acquiring the complete coverage of all angles of the object was not possible, particularly of overhead details. As such, of the dense point clouds generated from photography, many did not have data for the sides of the artefact or the deeply incised details on the top (for example, see figure 18). During the survey, several shots were taken from a distance, in attempt to achieve more coverage of artefacts at different angles, however the camera was in many cases too distant from the artefact, and the object was too small to fill the frame (see figure 3). This resulted in many of the smaller artefacts not processing correctly, as insufficient spatial data was available of them, while too much data was gathered of the background areas also featuring in the imagery.

It was suggested that a macro 85mm lens or a zoom lens would provide better coverage of a small artefact, as wider lenses are more appropriate for large scale objects or buildings. Filling the frame of a photograph with the artefact that is to be recorded is necessary to ensure alignment is correct, and this was lacking in the case of the small artefacts during the survey.

PLACEMENT OF ARTEFACTS AS AN AID TO PHOTOGRAPHIC RECORDING

The low level of both the desk and pallets that all of the recorded artefacts rested on made photographing the sides of the artefacts difficult, as the shots of the sides of the objects could only be taken from oblique angles using the tripod. This is not ideal for SFM photogrammetry, due to the increased likelihood of areas being out of focus, as the depth of field is limited. This problem resulted in the sides of processed artefacts being missing from the photogrammetric model, as there was insufficient data of these areas for the SFM programme to calculate their location.

It was suggested by Jon Bedford, Senior Geospatial Imaging Analyst at Historic England, that a bar attachment for a tripod would allow for greater overhead coverage of the artefacts, as the camera can be positioned directly above, with adequate counterbalances to prevent any risk of the camera tilting onto the objects being photographed. Additionally, moderate depth filtering in Agisoft Photoscan is suitable for the building of the dense clouds for objects such as relief surfaces.

To produce detailed and complete photogrammetric models of entire artefacts, it is advised that artefacts are securely and safely raised above the floor level to ensure their sides are fully covered by photography.

On return visit, a cardboard box was used as a makeshift pedestal to boost the height of the small artefacts. A piece of white paper was placed on its surface for the artefacts to rest on, to allow for easier masking of the ground surface. However, due to the increased height, a footstool had to be used in order for the photographer to reach the camera viewfinder when the horizontal bar was attached, making manoeuvring the camera and tripod set up difficult. Although the box worked as an improvised raised surface, it had to be manually rotated to allow for full 360^0 coverage of the artefact. A raised photographic turntable would have simplified this process and ensured the amounts of overlap in imagery was adequate.

For less stable artefacts, it is possible to create lightweight props to stabilise them for such photography. This would have been useful to photograph the sides of the artefacts, to fully record all sides of them in order to merge Photoscan chunks together to produce 360^0 3D models of them. As this was not possible at the time of recording, the faces of the artefacts which rested on the table were not recorded, and the 3D models do not feature their bases as a result.

LIGHTING

Two small LED light panels were used to aid in evenly lighting the small artefacts in the office room, as the electric lighting was directly overhead and strong. The office lighting was not turned off as staff members were working during the duration of the photographic survey, however this caused problems in recording of a medieval jug, as it caused substantial reflection on its glazed surface, and a lack of lighting placed above the jug meant that the interior appeared only as dark shadow in overhead shots. As SFM photogrammetry ideally needs flat, even lighting across the entire surface of the feature that is to be processed, more lighting control is needed to achieve this. Lighting boxes can be used to diffuse light evenly, so an artefact placed inside is not lit harshly from different angles.

In the second survey, no LED light panels were available, so the office's table desk lamps had to be used, which were not ideal due to varying brightness levels. To properly light an object for photography, a studio photography set up is required with a minimum of 3 studio lights.

RECORDING STUDIO SPACE

The crowded office environment and tightly packed warehouse shelves made minimising unnecessary features in the background of photos very difficult. This made the masking process very long, as areas other than the recorded artefact had to be manually masked in Photoscan, as opposed to using the quick "magic wand" function that can automatically select and mask blank areas of even colour (figure 23).

Figure 23: The masked area of the photograph is darkened, whilst the area that is to be processed using SFM is not. Note how much of the frame is taken up with areas that are not to be processed, due to the wide angle lens and also the arrangement of the pallet and its surroundings.

Additionally, the tight spaces available for photography during the survey made taking sufficient overlapping photos of the entirety of an artefact challenging, and the tripod had to be frequently moved, lowered or raised depending on the vicinity of the camera to the object.

Ideally, a photographic studio space should be set up and used. If a turntable was available, this would reduce the amount of space needed, as the artefact can be rotated as opposed to physically moving the camera to photograph different areas of the object. Additionally, a plain background can be set up around a studio and on its surface, making masking a more efficient process, with a complete lighting set up arranged that is dedicated to artefact photography.

RETURN VISIT

After initial processing of the first set of imagery, a bar attachment was borrowed for overhead photography of the 19th century seal box, which produced better coverage of the tops of the objects photographed. However, the lack of a fully controlled photographic studio suitable for object photography still made comprehensive coverage of every side and face of the object difficult, as we were restricted by the position and height of the table used to rest the artefacts on, and the necessity to stand on a stool to use the camera viewfinder to take photography. In hindsight, the focal length of the zoom lens should have been secured to ensure it did not slip, as this occurred due to the downwards position of the camera.

COMMENTS ON SUCCESSFUL SFM PROCESSING

All of the stone artefacts that were photographed from pallets processed successfully, albeit some with missing sides where it was not possible to take enough overlapping photographs of certain areas due to their close placement beside other pieces of sculpture. The varied texture of non-polished stone generally works well for SFM photogrammetry, which works on the basis of identifying and aligning specific points across a series of overlapping photos and placing these spatially (see The Survey Association 2016 or Bedford in press, for more information on the process of SFM). As such, it can be suggested that SFM can further be used as an approach to recording medieval stonework in future, for the Helmsley Archaeological Store, preferably if each piece is placed on a raised plain flat surface on top of a separate pallet, which could be rotated, or with sufficient space for a photographer to manoeuvre a camera and tripod around.

The bubble wrap surface that the initial set of small artefact photography was taken against caused issues in SFM processing, in that the varied texture of the bubble wrap became the focus of the processing due to the amount that filled the frame of shots instead of the artefacts themselves. As such, it is suggested that a similar set up to the photographic studio approach described above, is taken, for more successful SFM processing in future.

PART 5: CONCLUSION

Overall, the project has provided an extremely useful learning experience in the highlighting the technical requirements of producing high quality photographs of artefacts that can be used for SFM photogrammetry processing. Since the fieldwork has been conducted, the Historic England Geospatial Imaging team has purchased lighting and photography equipment for improved studio photography of small to medium-sized objects. Light boxes, LED light panels and green screens all aid in providing more controlled conditions for evenly lit and unobstructed photography of artefacts, however awareness of the requirements for SFM photogrammetry, and skill in producing the photography to meet such demands remain the essential aspect of successfully creating high quality, accurate 3D models of artefacts.

The artefacts to be recorded did not fill enough of the frame of each image, due to the large size of the table used to rest them on. The limited range of the tripod in the tight space that the larger, stone artefacts were placed in meant that not all areas of the artefacts could be photographed with adequate overlap for successful photo alignment in Photoscan, meaning certain areas were not covered.

It is highly recommended that a photographic studio space can be set up when photography of small artefacts is needed for SFM within the Helmsley Archaeological Store. If placed in an area without obstruction, such a space does not have to be overly large, as a turntable would alleviate the need for the photographer to move around an object. Under the Shared Service agreement, Historic England's Geospatial Imaging team has the equipment and means of aiding in such recording work, and this report has demonstrated how usable results can still be generated even when recording conditions are not ideal. With the lessons learnt from this experimental project, it is hoped that the suggestions made highlight how beneficial SFM photogrammetric models of high quality can be for the English Heritage Curatorial Team, particularly when artefacts have moved on from the store to be placed on display elsewhere.

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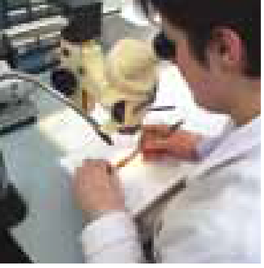
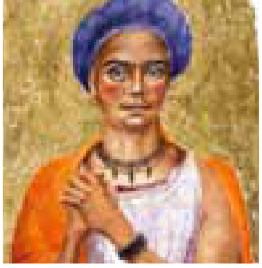


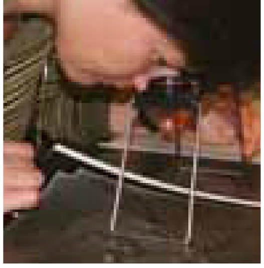


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