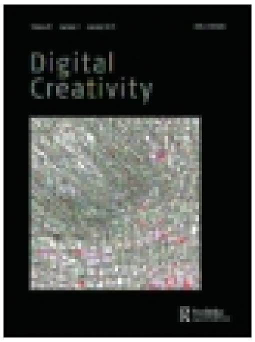


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# Digital sculpting for historical representation: Neville tomb case study

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**ABSTRACT**
Despite digital 3-D polygon modelling applications providing a common and powerful tool-set for archaeological, architectural and historical visualisation over recent years, the relatively recent developments in high-resolution sculpting software allow for the possibility to create digital outcomes with a degree of surface fidelity not previously obtainable from the more widely used poly-modelling software packages. Such digital sculpting applications are more commonly applied within the video games and TV/motion picture industries, the intention of this paper is to show how such tools and methodologies together with existing scanned data and some historical knowledge can remediate and re-imagine lost sculptural form. The intended research will focus on an examination and partial re-construction of the tomb of Sir John Neville, 3rd Baron Raby located at Durham Cathedral, County Durham UK.

**KEYWORDS**
Digital sculpting; visualisation; laser scanning; photogrammetry; virtual Heritage

## 1 Introduction

Digital sculpting and 3-D scanning are well used in the game design industry and more recently they are also being evaluated and tested by various researchers for product design development and for organic concept generation (Alcaide-Marzal et al. 2013). In the archaeological and heritage sectors, these tools are rarely combined for digitally restoring lost or partly damaged artefacts, but rarely are these tools combined (Unver and Taylor 2012). In this paper, the potential for the combination of 3-D scanning and digital sculpting was assessed for its application to the heritage industry and the authors propose that by combining these digital tools, the visualiser can get closer to an efficacious 3-D representation or reconstruction.

Bernard Frischer, Director of the World Heritage Laboratory at the University of Virginia, calls the Wests post-Gothic compulsion to visually interpret the past a ‘humanistic code’ (2008). Prior to the development of digital technologies to facilitate cataloguing, understanding, safe-keeping and communication, drawings such as plans, sections, elevations and axonometric illustrations were used to describe monuments, buildings and artefacts, though such recordings suffered in their limitations of representing 3-D form. The power of 2-D visualisation to re-enforce human cognition is well recorded (Tufte 2001; Ware 2008) but argues that 3-D visualisation enables more complex analysis to be undertaken.

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The first Computer Applications and Quantitative Methods in Archaeology (CAA) conference noted the value of 3-D modelling within archaeology and historical illustration for Data Banks and Information Retrieval, Statistical Analyses, Recording of Fieldwork and the Production of Diagrams (Wilcock 1973). Eleven years later, the BBC broadcast a 3-D recreation of the temple below the Pump Room at Bath, bringing digital reconstruction to a lay audience and provided a catalyst for further 3-D representation research (Lavender 1990).

Interactive digital study provides re-creation (s) of past objects, archaeological sites or events that can aid understanding for a wide variety of audiences (Reilly 1989; Marichal, ICVS '01). The virtual assembly of relic fragments, environments and online games are used in the analysis reconstructions of large-scale spaces, the recording and digital preservation of cultural heritage sites (Gill 2009). Experiments in 3-D scanning and architectural modelling are being used in digital cultural heritage, cyber archaeology and serious gaming research and these approaches offer opportunities for bridging the gaps among conservation, digital curation and metric survey (Anderson et al. 2009; Foni and Magnenat-Thalmann 2003; Unver, Atkinson, and Tancock 2006).

For the commissioners, makers, researchers and audience, there are questions that need to be asked concerning the veracity of digital reconstruction and representation. The prevalence of 3-D digital visualization and more complex CAD packages used in the entertainment industries has led to criticism that visualisations can become '… vehicles for demonstrating advanced graphics techniques with any archaeological considerations playing a less important role' (Ryan 1996). In addition, there is a possibility for the misrepresentation of archaeological sites, for when material or data are absent, the digital can visualise a hypothesis, which could then be read as authentic (Richards 1998; Levy 2001; Donnell 2012). Favro calls this 'false viewing' (2006) and Mosaker agrees that a digital simulation can not represent the original as it is divorced from its original setting resulting in a less 'original experience' (2001). Taylor and Unver have described the process of needing to consider what constitutes 'worthy content' (Unver and Taylor 2009; Rosenstone 1986). Nichols (2001) and Hathaway-Smith (2010) worry that the lay-public has limited knowledge to understand the value of such material and as such, a simulation may suggest that it displays the 'truth'. When digital sculpting and 3-D scanning are well used in both game and product design and in the archaeological and heritage sectors, but rarely are these tools combined (Unver and Taylor 2012).

More recently, digital sculpting software applications such as Pixologic *ZBrush* and Autodesk *Mudbox* enable the creation of intricate forms which resemble the additive interface of clay modelling. This has encouraged traditional sculptors and modelors to work in digital clay (Pernot et al. 2008). In this paper, the potential for the combination of 3-D scanning and digital sculpting was assessed in its application to the heritage industry. The authors propose that by combining these digital tools, the visualiser can get closer to an efficacious 3-D representation or reconstruction.

Traditionally, the archaeologist would use artist/illustrators to visualise/interpret research investigations of lost artefacts. 2-D illustrations would be produced providing separate visuals for each iteration of the final artefact. If 3-D representations were required these would be produced by professional modelmakers, a time-consuming and expensive process and one that may not provide sufficiently accurate representation. The process undertaken here allows for rapid iteration and application of research findings through a flexible and speedy change to the 3-D sculpt. The application of symmetry modification, layering and similar advanced tools enable the dynamic application of texturing and surface details.

## 2 Materials and methods

The aim of this work is to test the use of digital sculpting 3-D modelling tools and methodologies together with existing scanned data and historical knowledge to remediate and re-imagine lost sculptural form. The intended research will focus on an examination and partial re-construction of the tomb of Sir John Neville located at Durham Cathedral, County Durham, UK.

Traditionally, digital models can be divided into three types:

- Polygonal models are made up of a collection of points, edges and polygons.
- NURBS surfaces consist of a network of curves with smooth surfaces between them.
- Subdivision (SubD) surfaces are similar to polygonal models because they are made up of points, edges and polygons but also share some of the benefits of NURBS surfaces, placing them into their own category.

Further, digital modellers are often categorised as hard-surface or organic, modellers and can sometimes entirely specialise in one or the other types of outcome. The practical part of this test was carried out by an experienced creative educator, skilled in freehand and digital design practice. Figure 1 shows the research methodology, process and planning applied.
Our interest is to examine the use of the following methods and their appropriateness for digital heritage.

1. The use of photogrammetry and laser scanned data for creating 3-D cloud data.
2. The transformation of this cloud data for polygonal mesh re-topology for clean surface creation using sculpture modelling tools for digital restoration and construction of 3-D mesh data.
3. Testing digital painting and texturing.
4. Creation of 3-D printed digitally restored artefact.

## 3 Experiments

The tomb of Sir John Neville (Figure 2) is an example of cultural vandalism and has undergone progressive damage at key moments throughout several hundred years of regional social and religious upheaval.

The Nevilles rise to prominence in the late 1300s was the direct result of associations cultivated by Sir John's father and further expanded by his own son Ralph, first Earl of Westmoreland. The tomb is typical of the age of its construction. To the medieval observer, this carved representation with its use of typifaction, heraldic iconography and polychromatic paint and gilt provided not only a focus of devotion and memory, but of an ideal of the notion of chivalry and of political power and affiliation (Arvanigian 2000). In selecting the tomb of Sir John Neville, an opportunity arose to investigate digital processes within the realm of sculptural remediation. Whilst the base of the tomb is largely intact despite some quite heavy damage, little remains of the sculpted effigies of Sir John and his wife, and so the initial decision is based upon the challenge of partially re-creating the stone carving and lost sculptural form.

The reinstatement of lost form is to be achieved through the use of a combination of scanned data visual research and a degree of artistic licence. The intention is not to declare a historically 'true' image, but to examine processes and techniques that may or may not contribute to such endeavour. Visits were undertaken and permission sought to enable a scanned survey to be undertaken.

### 3.1 Site-specific data capture and translation

A series of scans were taken of the surface using a portable 3-D laser scanner (Figure 3). The Minolta scanner captures the object surface from a single point. On activation of the scanner, the laser moves across the target object.

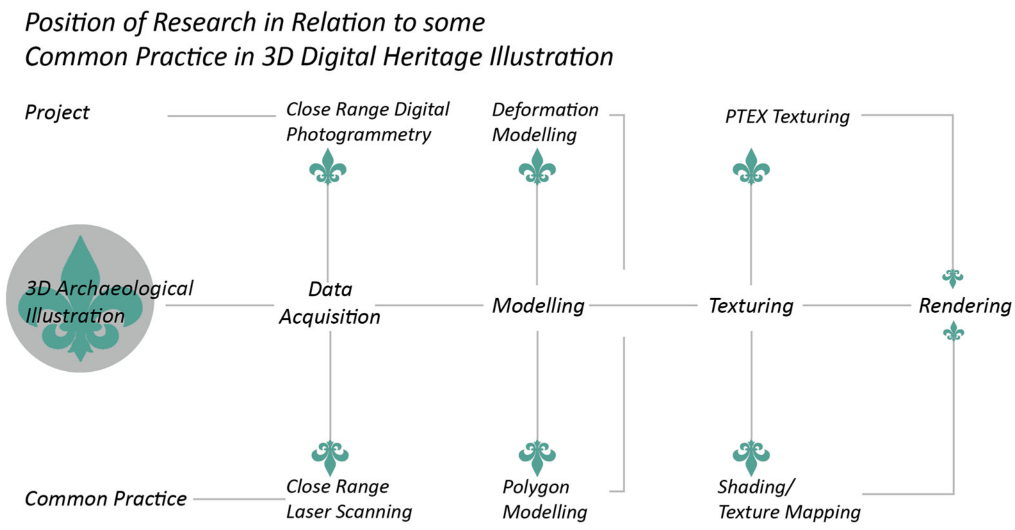


**Figure 1.** Digital design methodology applied.

The laser touches the object and the light is reflected back to the scanner, which captures the surface data of the shape, and records the measurement of an object at a distance between 50 cm and 3 m. The measurements are translated into an impact location, and are then displayed by the software as cloud point data, or cloud data which initially form the 3-D shape of the recorded object in the 3-D software. There was a certain amount of restriction given the location of the tomb; however, enough data were captured to allow for an attempt at test retopology.

The data were then imported to Geomagic Studio, transforming 3-D scan information into usable 3-D polygonal, surface and CAD data. The results were patchy, but there was enough to be able to reconstruct the largely

**Figure 2.** The tomb of Sir John Neville.

**Figure 3.** The Minolta 3D scanner used to scan the surface topology of the tomb of Sir John Neville.

**Figure 4.** Geomagic scanned data checked against Image.

repetitive elements that surround the tomb. Once the data transferred to a computer there was a need to check it for its relative position over a composited image file, as shown in Figure 4.

### 3.2 Modelling and sculpting

Compared to traditional polygon modelling techniques, digital clay modelling introduces ambiguity, imprecision and plasticity. These properties lend themselves to exploitation by designers used to haptic and intuitive mark making. Surface changes are modified using digital pen strokes.

The use of 3-D scanned data provides a starting point to enable an artistic visualisation. Through the application of processes used within the games industry, the research demonstrates how such methodology applies to heritage reconstruction. Software employing digital sculpting tools include Mudbox, ZBrush, Blender, Silo, 3D-Coat and Modo. A number of these have been successfully used by the digital entertainment industries, for their ability to use millions of polygons utilising a brush-based system that allows for the creation of highly detailed meshes that were not possible until recently. Although these high-poly meshes are used in their own right, they are also applied as source material to enhance low-poly models used in real-time games with the use of displacement, bump and normal maps. This mapping option uses pixels containing the high-resolution mesh data to fake the lighting of raised and recessed areas on a surface, which allow for low-resolution game models to display the details of a high-poly sculpt.

For the most part, the 'hard-surface' qualities of the tomb base were predominantly modelled in the poly-modelling application in 3D Studio Max. Whereas the effigy was sculpted in the deformation modelling package Mudbox, in keeping with the nature of the organic human form and loosely reflecting something of the qualities of sculpting upon a single object.

The files were assembled and holes were filled where appropriate. Initially, the data were imported to 3D Coat software; however, a preference for the re-topology tools in 3D Studio Max enabled a more speedy approach to testing than re-building the base (Figure 5). Initially, taking some of the basic carved forms, an examination of the step build method was undertaken and then exporting to Mudbox was attempted.

Figure 5. Import of stitched data to 3D Studio Max.

### 3.3 Base modelling

The different constructive and carved nature of the base of the tomb and the sculpted effigy upon it provided a different approach to capturing the surface data and for testing applications to the modelling of the surface. A step build method was initially undertaken in attempting to develop a satisfactory workable topology. This time-consuming process requires maintaining control of the topology and keeping a clean mesh. The base mesh and

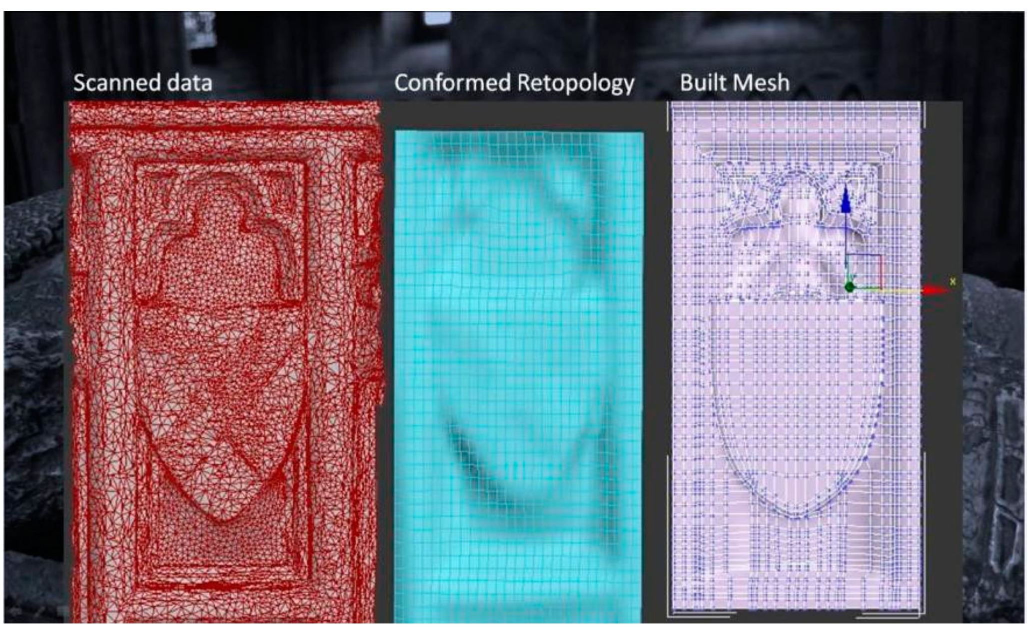


Figure 6. Two different approaches next to the original scanned data.

a mesh using the conform/re-topology method, as well as a mesh built using a more traditional approach using the scanned data are all utilised as reference only. The initial attempt at a built mesh still attempted to maintain a unified, single quaded approach with a polygon density high enough to capture surface detail and the nature of the carved stone. The result, however, provided an inelegant and complex outcome that ultimately would be unworkable for 3-D sculpting (Figure 6).

Once the smaller decorative elements were created, another method for the recreation of the main parts of the base was investigated. In order to establish an efficient approach, initially existed repeating surface topologies are constructed to form the major section of the base. The method chosen was to build a structured base mesh that could be carefully referenced over the scanned data. There was no part of the tomb from the scan that afforded enough clean and undamaged topology to create an accurate enough conformed mesh.

Further elements to the base of the tomb were made, including the addition of the stepped section, the lower base and the castellated top of the tomb created earlier. Using instances of these sections, the base was extended and copies were made for the construction of the corner pieces (Figure 7).

### 3.4 Typifaction in tomb effigy—seeking historical precedents

At this point, with no evidence as to the likeness of Sir John Neville, further research was undertaken to locate evidence that might provide some clues as to this. Paul Binsky's, Medieval Death, Ritual and Representation, helped provide some of the answers to this problem. In particular, he highlighted issues around typifaction at this time and a further investigation lead to a realisation that the great majority of the tomb effigies of the period represented a standardised ideal rather than an actual likeness (Binsky 1996).

It is fortunate then in this case a visualiser can to some degree make informed guesses as to the possible sculpted likeness of the effigy. The images below show just some of this typifaction, with figures showing a male face in repose, eyes open with moustache usually falling outside of a sculpted chainmail avontail (Figure 8). Further to the examples of typifaction it was becoming apparent that there was clearly a need to examine aspects of the application of polychrome clearly evident in some of the examples above.

**Figure 7.** Completed sections with symmetry and with corner elements added.

**Figure 8.** Examples of typifaction in contemporary tomb effigy: Left to Right: Edward Prince of Wales, Canterbury. Alexander de Mowbray, Saint Michael, Kirklington and John Beauchamp, Worcester Cathedral.

### *3.5 Application of polychrome*

With regard to the Neville tomb, there is clearly evidence of colour but it is difficult to find if this has been added or retouched at points in history, or if was part of the design of the tomb at the point of its construction. What is clear is that more polychrome is apparent on the side of the tomb facing the Nave of the Cathedral than that on the South Aisle (Figure 9).

Within the cathedral, there are examples of polychrome that give a greater indication of the level of application that might have been present earlier in its history. The tomb of

**Figure 9.** Tomb viewed from the Nave with evidence of polychrome.

**Figure 10.** The Chantry of Bishop Hatfield, Durham Cathedral.

Bishop Hatfield, a contemporary of Sir John, lies in the North Choir and has much of its original polychrome in evidence (Figure 10).

Further similar examples of this application of colour can be seen at Exeter where extensive restoration work of the polychrome completed on two of the Cathedral's matching tomb canopies, that of Archbishops Stafford and Branscombe. These data were applied and are discussed in Section 3.10 of this paper.

### 3.6 Photogrammetry testing

The original laser scan of the alabaster figure of Sir John provided insufficient data on a number of levels. Whilst the scan is of high detail, the difficulty of the location in capturing satisfactory data, alongside the obvious damage to the effigy prompted the search for alternative approaches. The absence of much of the sculptural form of the effigies upon the tomb meant that a search was undertaken to locate a contemporary alabaster effigy to Sir John. In locating this, an opportunity arrived to use the Autodesk 123D Catch photogrammetric software. An alternative approach to laser scanning, photographs can be taken using a digital camera and aligned together, the camera positions are then calculated and a point cloud is produced. There are some advantages to using a Photogrammetry method, it requires little user expertise, there is no need for expensive 3-D scanning equipment. It can produce relatively accurate 3-D digital models based only on photographs taken using a standard camera.

Investigation into the recording of medieval church monuments led to the work of Charles Alfred Stothard (5 July 1786–27 May 1821), a draughtsman whose body of work catalogued a great many of these sculpted effigies.

One of the Stothard drawings showed a tomb located in St Boniface Church in the village of Bunbury, Cheshire. The Tomb of Sir Hugh Calveley c.1315–1394 is considered one of the best surviving examples of alabaster tomb carving in the north of England (Figure 11). Permission

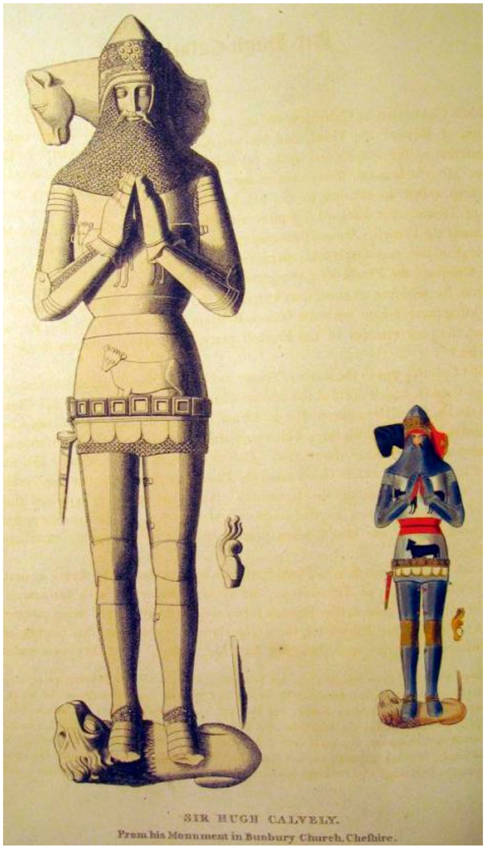


**Figure 11.** Sir Hugh Calveley.

was sought to undertake a photogrammetry survey of the tomb. The intention was to use the resulting 3-D model developed from over 180 digital photographs to allow for the building of a base mesh in 3D Max that would conform to something like the effigy on the Neville tomb.

The images were uploaded via 123D's desktop software to be rendered together. Initial results were disappointing, but after careful selection of relevant images and splitting the process into head, torso and legs and combining the data in 3D Max, a better result was achieved. Fewer images were used here, just from the top half of the effigy, producing a better outcome. Once the scans were cleaned up and combined, it was discovered that there was sufficient data to make some initial attempts within 3D Max to use the Conform tool to create useable surface data and experiment by creating a base mesh (Figure 12).

The choice of this method was one based upon the particular nature of the carved alabaster. Whilst we cannot fully replicate the subtractive nature and natural consistency of alabaster sculpting, it was hoped that the attempt at creating a single topological surface that conformed to the underlying shape might help reduce the tendency to follow traditional poly-modelling approaches to produce a clean base mesh.

### *3.7 Modelling and sculpting the effigy*

After capturing the data from the tomb of Sir Hugh Calveley and importing into 3D Studio Max, texture details were removed and initial attempts at using the conform method were applied. These data were good enough for a rapid production of a quaded mesh produced using this workflow, it became apparent that some serious surface problems are encountered when a more complex topology is used (Figure 13).

If the conformed mesh is to be successfully imported and sculpted upon, then this method cannot produce a satisfactory base mesh for import, as areas of the surface have very complex topology producing distortions in the mesh that would become problematic for sculpting. The dense level of the mesh and this uneven topology could be seen more clearly when the file was exported to Mudbox where higher subdivision levels were applied. The result was an altogether unsatisfactory outcome and one that required so much remedial correction as to be impractical to work with. A decision was made to retopologise the parts of the conformed mesh that were problematic and to reduce the initial level of topology (Figure 14).

At this stage, limitations in hardware had a significant impact on performance with this mesh. The relative differences in how the two

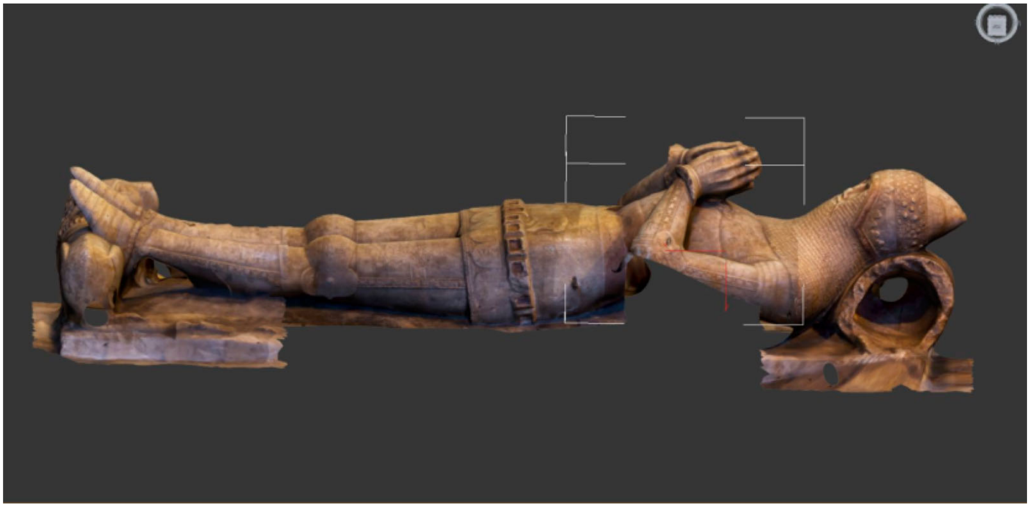

**Figure 12.** Scanned data combined in 3D Studio Max.

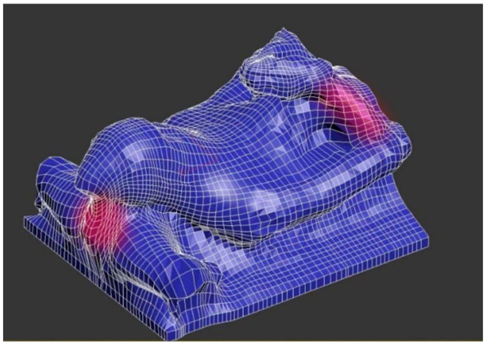

**Figure 13.** With some of the problems highlighted.

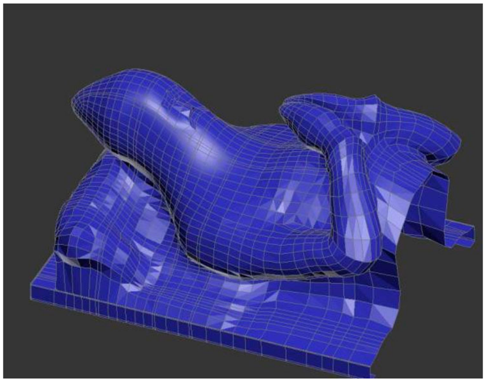

**Figure 14.** Retopologised corrected mesh.

major sculpting applications (Mudbox and ZBrush) use hardware within the computer highlighted how effectively the mesh could be sculpted. It was therefore necessary to obtain a workstation capable of dealing with a high level of polygons. The final model scanned retopologised and conformed lower section of the figure was added and asymmetrical elements such as the helmet and the lion constructed (Figure 15)

### *3.8 Digital sculpting in mudbox*

After creating a clean tological base mesh, the data are transferred to Mudbox digital clay modelling software for sculpting initial major forms. Once some of the tertiary forms had been added to the sculpt (Figure 16), it was then necessary to proceed onto some of the detail sculpting. At most stages up to this point, the mesh had been subdivided to a maximum of approximately three million polygons. In order to apply the greater detail, the model was subdivided to a level of 14 million polygons. This not only allowed for direct sculpting of detail but the application of custom stencils developed in Adobe Photoshop and Illustrator

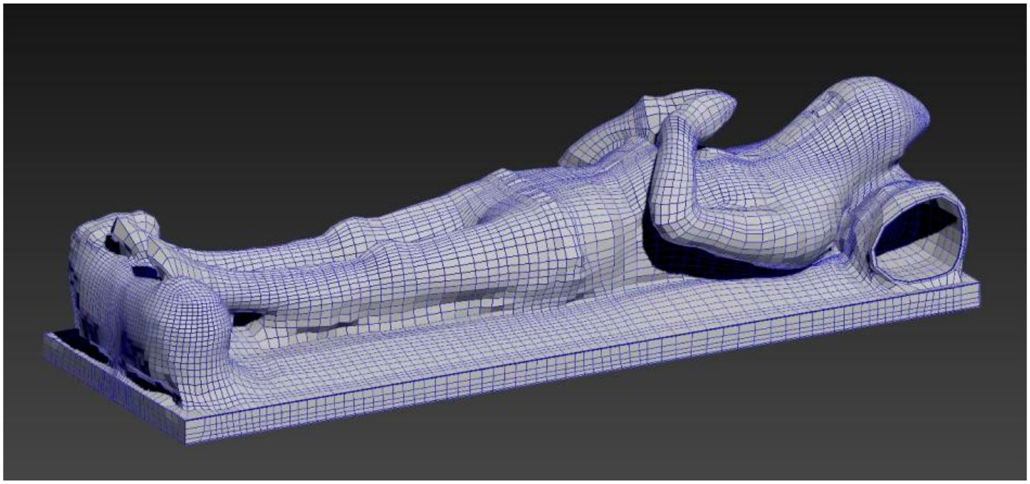

**Figure 15.** Showing the basic asymmetrical elements added.

**Figure 16.** In Mudbox Sculpting with some of the tertiary forms.

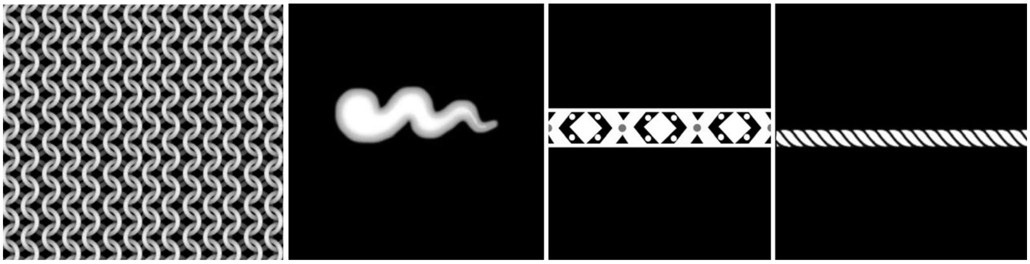

**Figure 17.** Some of the 14 custom stencils made to aid sculpting.

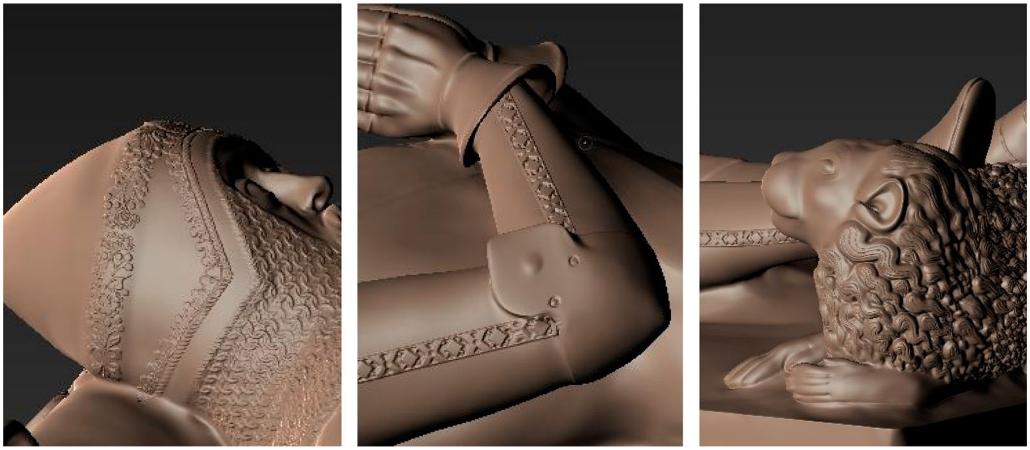

**Figure 18.** Stencil application on the model.

and imported as TIFF files into Mudbox. These stencils included Chainmail, Belt detail, detail for the carved lion and decorative edging for armour basinet and helmet.

Where no direct information was available, 'placeholder' graphic elements were added. These are easily removed should the input of correct data be forthcoming. Examples of this include the stencil created for the armour trim seen above (Figure 17).

The helmet was sculpted from the base topology imported. However, the sword was modelled separately in 3D Studio Max and imported as an .FBX file and added to the scene in Mudbox. Polygon modelling and digital sculpting generally work in tandem. The visualiser uses a combination of tools across a number of software applications in an effective pipeline and therefore the users must have advanced understanding of the different approaches required and the range of tools and techniques needed to achieve the level of detail needed (see Figure 18).

**Figure 19.** The sculpted effigy of Sir John Neville positioned on the modelled tomb base.

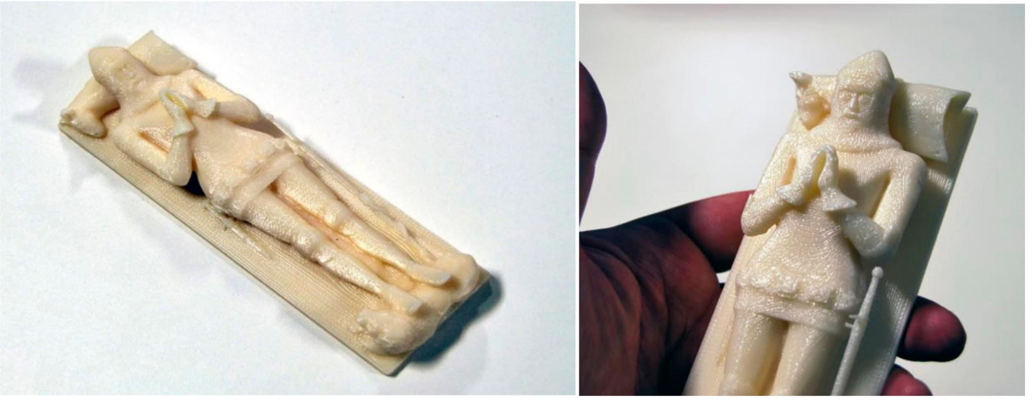

**Figure 20.** Final 3-D print after removal of the support material.

The individual sections model and details are assembled in 3D Studio Max for final renderings as seen in Figure 19.

### 3.9 3-D printing

3-D printing uses the method of additive manufacturing, the process of joining materials to make physical objects from 3-D model data. Applications of 3-D printing to heritage model making and visualisation could be small prototypes to be used as tactile objects, for those with visual impairment, or to heritage merchandise for sale or for the production of full scale replicas.

The intention to 3-D print a small part of the model allowed for the opportunity to exploit some of the tools within the ZBrush sculpting application. At 14 million polygons the subdivided mesh would provide issues around import and manipulation into 3D Studio Max for export as an .STL file. However, ZBrush can manipulate such subdivision levels and has a number of plug-ins that will allow for mesh decimation and the output of an .stl file. Therefore, the model was imported into Zbrush as a ZTool and the mesh reduced by using Decimation Master plug-in. The process significantly reduced the size of the mesh without compromising details, it does, however, prevent any further sculpting. After the mesh was decimated, the file was prepared for printing via a Dimensions Elite 3D Printer (Figure 20). 3-D printing allows for most sizes, but cost needs to be considered.

### 3.10 Colouring and texturing

Texturing is a method for adding colour details and applying 2-D images onto 3-D surfaces with appropriate scale and layout. Autodesk Mudbox software enables user to use UV mapping or PTEX mapping. A brief investigation into the application of some of the polychromy on the tomb would allow for an examination of PTEX Texturing. PTEX is a relatively new texturing system developed by Walt Disney Animation Studio for production quality rendering. Traditionally, texture or UV, maps are created to store texture placement. UV coordinates are a 2-D representation of 3-D space. They set up a relationship between a 2-D image and the 3-D surface the image will be applied to. PTEX stores a separate texture per face of the subdivision control mesh, each of which can be independently sized, and any surface can be mapped with a single PTEX file containing all of the per-face textures regardless of mesh complexity, the file also contains mesh adjacency data that is used to filter across faces.

The residual polychrome on the tomb base gave enough data to begin to examine how the tomb may have looked when first applied (see

**Figure 21.** Details of test custom material, texture, diffuse and specular paint layers in Mudbox.

Figure 21). Part of the modelled tomb section was imported into Mudbox for the final sculpting of the decorative elements, such as scroll work and leaf carving. Once imported the mesh was subdivided and prepared for PTEX texturing.

Based on Photographs taken on visits to Durham, using Photoshop software the RGB colour information was used to recreate colour information in Mudbox and applied to the sculpted model. Two further custom stencils

**Figure 22.** Sample polychrome applied to the tomb and effigy.

were also created for the lion ‘rampant’ and saltire carving on the shields. Diffuse and Specular texture layers were created for the ‘gold’ effect. Colour application and the decorative sculpt on a textured stone base was added (Figure 22).

Figure 22 shows the final application of colour onto both the tomb base and the effigy. Decisions as to its application to the model were based upon both evidence of residual polychrome upon the tomb and authors artistic impressions.

## 4 Findings

The application of digital sculpting is still predominantly used for the modelling of organic outcomes. Its particular nature lends itself to those disciplines where human and natural form is to be represented. The research here is intended to demonstrate that where the representation or remediation of a sculptural artefact is required, such approaches may be an alternative worthy of consideration to traditional additive or glyptic sculpting.

Critical engagement with heritage images and the repercussions of their use have resulted in a more reflective consideration of the issues of historical legitimacy and the effects of their distribution for public consumption (Taylor, Unver, and Benincasa-Sharman 2012). In the course of engaging with new digital practices, this research allowed for an examination of a number of software applications and approaches. Towards the very latter stages of this project, more recent developments in the associated software resulted in some of the processes outlined here becoming a legacy workflow. However, the fact that they are now integrated into digital sculpting applications demonstrates the perceived need by developers that workflows, involving efficient handling and manipulation of scanned data, mesh reduction, automatic and user-defined re-topology options and powerful sculpting tools that mirror this projects intentions, are natural additions to such software.

With the use of pressure-sensitive tablets, or even future integration of haptic feedback devices, visualisers are able to shape and form virtual materials at much higher polygon density and therefore apply a much greater degree of texture and surface details to an object. With the production of highly detailed models, the opportunity arises to use new 3-D printing devises to produce tactile outcomes that demonstrate this level of fidelity. In addition, such surface details can be ‘baked’ onto lower resolution meshes to allow for the representation of similar visual details for web-based media and animation output. It is the nature of these new digital sculpting tools that they provide, through sculpting layers, stencils, displacement maps and texture layers. A flexible and interpretive non-concretised skin, offering an almost tactile real-time deformation that could play a part in helping formulate such reconstructive decisions within a shorter space of time. Work that now becomes a process for critical debate, the registering of conflicting interpretations and the expansion of research, rather than just simply a highly finished outcome.

## 5 Conclusion

Traditional sculpture has long expressed such a form in the tactile plasticity of clay and similar materials, either at the initial stages of design or as an end result. The digitally sculpting software used here does demand a significant learning curve to master the sometimes complex user interface and tool sets needed to develop the sculpted outcome. However, once mastered, these relatively new digital sculpting tools allow for similar approaches that rely less on a formal understanding of polygon modelling disciplines and a more intuitive and naturalistic approach to creating forms.

One of the main advantages of this digital clay modelling method is that the final output, whether a render, animation or a 3-D printed model, allows for discussion of a work in progress and can be modified and improved with input from the digital creative, historian or heritage body. Whereas traditional conservation may directly affect the original artefact, and can incur significant time and material costs. This research demonstrated that digital clay modelling tools can be successfully integrated into the field of archaeological reconstruction to enhance visual and 3-D depictions of damaged or lost artefacts. Although the process shares similarities with the gaming and animation industries, it has great potential for historical reconstructions.

The authors acknowledge that a wider variety of lost or damaged archaeological artefacts should be reconstructed using the method applied in this research, so as to test the efficacy of this experimental approach to other artefacts and materials. Levels of accuracy within the process will be dependant on the nature of the captured data and mitigated by the requirements of the client. Demonstrated here is a process that may provide for input from a variety of specialists to visualise the lost form and therefore, in extending this project, it would inevitably include the involvement of relevant expertise from a number of disciplines to ensure respect for authenticity. The authors intend to seek comments and input from professionals such as museum curators, historians, archaologists and archaological/heritage visualisation specialists to explore this workflow further.

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*Caterina Benincasa-Sharman* is interested in transdisciplinary research and has contributed to debates surrounding the pedagogy of theoretical and historical studies in art and design settings. She is also interested in authenticity, identity and place-making as represented and seen in ephemera and the built environment. The main focus of her current PhD research looks at the events and outputs that made up the 1951 Festival of Britain celebrations in Leeds, York, Hull, Manchester and Liverpool. These cities used the Festival of Britain to consolidate their identities of place and space in a post-war world, often restoring, preserving or creating new buildings of architectural significance. Cate has spoken about her research at Social, Urban and Modern History Conferences.

## References

Alcaide-Marzal, J., J. A. Diego-Más, S. Asensio-Cuesta, and B. Piqueras-Fiszman. 2013. "An Exploratory Study on the Use of Digital

Sculpting in Conceptual Product Design." *Design Studies* 34: 264–284.
Anderson, E. F., L. McLoughlin, F. Liarokapis, C. Peters, P. Petridis, and S. de Freitas. 2009. "Serious Games in Cultural Heritage." Paper presented at the 10th International Symposium on Virtual Reality, Archaeology and Cultural Heritage VAST St. Julians, Malta — September 22–25, 2009 – State of the Art Reports.
Arvanigian, M. E. 2000. "The Nevilles and the Political Establishment in North East England 1377–1413." PhD diss. Durham: University of Durham.
Binsky, P. 1996. *Medieval Death, Ritual and Representation*. Ithaca, NY: Cornell University Press.
Donnell, D. O. 2012. "Is There a Text in This Edition: On the Implications of Multiple Media and Immersive Technology for the Future of the Scholarly Edition." Accessed September 25, 2012. http://visionarycross.org.
Favro, D. 2006. "In the Eyes of the Beholder: Virtual Reality Re-creations and Academia in Imaging Ancient Rome." *Journal of Roman Archaeology* 61: 321–334.
Foni, A., G. P., and N. Magnenat-Thalmann. 2003. "A Virtual Heritage Case Study. A Modern Approach to the Revival of Ancient Historical or Archeological Sites." MIRALab, University of Geneva.
Frischer, B., and A. Dakouri-Hild. 2008. *Beyond Illustration: 2D and 3D Digital Technologies as Tools for Discovery in Archaeology.* British Archaeological Reports International Series
Gill, A. A. 2009. "Digitizing the Past: Charting New Courses in the Modeling of Virtual Landscapes."
Hathaway-Smith, M. 2010. "A Necessary Duty, A Hideous Fault: Digital Technology and the Ethics of Archaeological Conservation." Master of Arts. Texas: Texas A&M University.
Lavender, D. A. 1990. "Solid Modeling of Roman Bath." In *Communication in Archaeology: A Global View of the Impact of Information Technology*, edited by P. Reilly and S.P.Q. Rahtz, 7-13. Second World Archaeological Congress, Barquisimeto, Venezuela, September.
Levy, R. M. 2001. "Temple Site at Phimai: Modeling for the Scholar and the Tourist Proceedings of Seventh International Conference on Virtual Systems and Multimedia." *IEEE Computer Society* 7: 147–158.
Marichal, N. ICVS '01. "Interactive Immersive Transfiction." Paper presented at the Proceedings of the International Conference on Virtual Storytelling, Avignon, France, September, 27–28, 2001.
Mosaker, L. 2001. "Visualising Historical Knowledge Using Virtual Reality Technology." *Digital Creativity* 12 (1): 15–25.
Nichols, B. 2001. *Introduction to Documentary*. 1st ed. Bloomington: Indiana University Press.
Pernot, J.-P., B. Falcidieno, F. Giannini, and J.-C. Léon. (2008). "Incorporating Free-form Features in Aesthetic and Engineering Product Design: State-of-the-art Report. *Computers in Industry* 59(6): 626–637.
Reilly, P. 1989. "Data Visualization in Archaeology." *IBM Systems* 28 (4): 569.
Richards, J. D. 1998. "Recent Trends in Computer Applications in Archaeology." *Journal of Archaeological Research* 6 (4): 331–382.
Rosenstone, R. A. 1986. "History in Images History in Words." *Humanities Working Paper* 121.
Ryan, N. S. 1996. "Computer-Based Visualisation of the Past: Technical 'Realism' and Historical Credibility." Imaging the Past, Occasional Paper 114.
Taylor, A., E. Unver, and C. Benincasa-Sharman. 2012. 'Hyper naturalism and simulacra in Stonehenge art'. Paper presented at the 4th International Euro-Mediterranean Conference (EuroMed 2012), Cyprus, 29 October–3 November 2012
Tufte, E. R. 2001. *The Visual Display of Quantitative Information.* Cheshire, CT: Graphics Press.
Unver, E., P. Atkinson, and D. Tancock. 2006. "Applying 3D Scanning and Modeling in Transport Design Education." *Journal of Computer-Aided Design and Applications*, 3 (1–4): 41–48. ISSN 1686-4360
Unver, E., and A. Taylor. 2009. "An Art and Design Perspective: The Development of a 3D Interactive Saltaire UNESCO World Heritage Site." Paper presented at the The 10th International Symposium on Virtual Reality, Archaeology and Cultural Heritage (VAST).
Unver, E., and A. Taylor. 2012. "Virtual Stonehenge Reconstruction. Progress in Cultural Heritage Preservation." Lecture Notes in Computer Science Subseries: Information Systems and Applications, incl. Internet/Web, and HCI, 7616 (XXV). Springer, pp. 449–460. ISBN 978-3-642-34234-9.
Ware, C. 2008. *Visual Thinking: For Design*. Burlington, MA: Morgan Kaufmann.
Wilcock, J. D. 1973. "Science and Archaeology Paper Presented at the Computer Applications and Quantitative Methods in Archaeology (CAA)", Birmingham.