Non-contact 3D laser scanning as a tool to aid identification and interpretation of archaeological artefacts; the case of a Middle Bronze Age Hittite dice.

Françoise P Rutland and Annemarie La Pensée

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The images seen here are screenshots of a 3D data set created by 3D laser scanning a Hittite Dice. More information is given later in the presentation.
Overview

• 3D laser scanning at National Museums Liverpool,
• 3D laser scanning,
• Applications (archaeological artefacts),
• Identification and interpretation; case studies from the Garstang Collection
  – A MBA Hittite dice,
  – A MBA Hittite mould.

ANNEMARIE LA PENSEE:
I will begin by briefly explaining a little about 3D laser scanning and why we have these facilities at National Museums Liverpool. I will then highlight some of the applications that the 3D data created by laser scanning can be and has been used for. For this talk I have chosen examples that focus on archaeological artefacts. Finally we would like to present some recent work on identification and interpretation we have undertaken using this technology on two objects from the Garstang collection – a Middle Bronze Age Hittite Dice and mould.
At National Museums Liverpool (NML) we have been involved in the non-contact documentation of cultural artefacts using 3D laser scanning for over 10 years. The laser scanning section is based in the conservation division of National Museums Liverpool. We employ only commercially available, specialist yes, but commercially available hardware and software. In conjunction with the sculpture conservation section we are a financially self sustaining unit within the museum, and we undertake work on objects in our own collections and in the collections of other museums and heritage institutions.

The images seen here are; part of the skyline of Liverpool (left), the façade and main entrance of National Conservation Centre, NML (middle), and a life size marble sculpture of “Athena” during non-contact 3D laser scanning (right).
About 12 years ago the sculpture conservators at NML started looking at ways to record sculpture in 3D, using technology that was emerging into the mainstream in the aeronautical and engineering sectors. The sculpture conservators were particularly interested in documenting in 3D, examining tool markings, measuring change, and solving access issues to vulnerable objects. Solving problems such as these is still what we use the 3D data created by laser scanning for today.

The image on the left is a photo of a terracotta sculpture of Atlas (790mm in height) from the collections of the Rijksmuseum, Netherlands. The three images on the right are screenshots taken from different angles of the 3D data set created by laser scanning the terracotta sculpture. The sculpture was recorded in 3D by Conservation Technologies (NML) as part of the Drop Sculpture (Atlas) project by the artist Simon Starling and the Rijksmuseum. See http://www.conservering.nl/atlas/?q=video.
There are numerous methods by which a 3D data set of a surface can be created – and I believe the last talk you had here, given by Mona Hess of UCL, examined some of these. At NML we happen to use triangulation based laser scanning. This method is used for close range data collection, that is on objects rather than buildings or archaeological sites. It works, in a basic examination, by trigonometry. A laser emitter emits a low power beam which is projected onto the surface of an object. The reflected light is recorded by an off axis digital camera. The angle at which the light leaves the sensor is fixed and known, the distance between the emitter and the sensor is fixed and known, and the device is recording the angle at which the light returns to the sensor, and thereby recording the point on the surface of the object. The laser scanning systems we use typically record 32 000 points per second. In this way they record the surface as a series of points – or a point cloud (top right). We then use software packages such as Polyworks (InnovMetric Inc) to convert these points to polygonal meshes (middle right) which can be rendered and manipulated in 3D in a wide variety of ways.
Shown here is one of the laser scanning systems we have at NML. It’s a ModelMakerX sensor mounted on a Faro Seven axis gold arm. The laser emitter and off-axis camera I was talking about are located in the sensor (black box mounted on the end of the arm). The arm and the sensor are moved over the object being scanned. There is no contact with the object at any time during scanning. The coordinate measuring arm on which the sensor is mounted ensures that as long as we don’t move the base of the scanner or the object during data collection all the data will be in one coordinate system.

The images here show the non-contact 3D laser scanning of the lower jaw of a Roman Age skull known as Leasowe Man.
Once the data has been processed we get 3D models of the surface of the object. We do not record colour information with our systems. We only collect geometric information, that is x,y,z information for each data measurement, no r,g,b information. These models can be rotated and lit from any angle and can be used in a wide variety of applications. Our models have a typical resolution of 0.2mm with an accuracy of +/-0.1mm.

The images seen here are screenshots of a 3D data set of a Roman Age skull known as Leasowe Man. Further information is given later in this presentation.
Adding colour

As I mentioned, we don’t record colour using the systems we have at National Museums Liverpool, and for most of the applications we use the 3D data for this is not an issue, as we are purely interested in the surface geometry. On occasions however, colour is crucial for visualisation purposes. In cases such as this we can either map on high resolution photos in localised areas, or as we have here, we can create generic textures in software packages such as 3D Studio Max. However, this will only ever be a highly subjective interpretation of the colour of the original object.

The images seen here are: left – original object, middle – screenshot of the 3D data set created by laser scanning, right – screenshot of the 3D data set created by laser scanning with a colour texture applied.

This nutcracker (approximately 250mm in height) was recorded in 3D as a test object as part of the Pre-Hispanic Caribbean Sculptural Arts in Wood Project, led by Joanna Ostapkowicz of National Museums Liverpool.
The applications for which 3D data sets of cultural artefacts can be used for are numerous, and include archiving, documentation, monitoring, visualisation, on-gallery activities, education, conservation, identification and interpretation and in the following slides I have highlighted a few of these applications. I have chosen, in the main, archaeological artefacts as examples in the following slides.

The images seen here are: the height deviation map created using a 3D data set on part of a fossil (left), a screenshot of a 3D data set of a Roman Helmet (further information is given on the next slides) (middle), and a screenshot of a 3D data set (image mapped) of an Anglo-Saxon Brooch (further information is given later in this presentation).
In 2000 the Hallaton Fieldwork Group and University of Leicester Archaeological Services discovered a large collection of Roman artefacts in southeast Leicestershire. Most of the items discovered date to just before the Roman Conquest. The site of the find proved to be an internationally important ritual site dating to the generations before and after the Roman Conquest of Britain in the 1st century AD. Amongst the 5,000 silver and gold coins, jewellery and many other objects found, archaeologists discovered a unique iron with silver gilt decoration Roman parade helmet (of dimensions 360mm (H) x 450mm (W) x 140mm (D) , which would have been worn by a very high ranking cavalry officer in the Roman army. The helmet was purchased by Leicestershire County Council with Heritage Lottery Funding. It was excavated, documented and conserved at the British Museum before going on display for the first time in the Hallaton Treasure exhibition at Harborough Museum, which opened in autumn 2009. Detailed excavation of the helmet revealed the image of an emperor on horseback on one cheek piece. Conservators at the British Museum asked Conservation Technologies at National Museums Liverpool to scan the helmet to provide a 3D document of the find during excavation and conservation. Conservation Technologies used a portable, non-contact Konica Minolta Range 7 close range laser scanning system to produce a highly accurate 3D computer model of the partially exposed helmet. This Roman Helmet from Leicestershire was undergoing excavation and conservation treatment at the British Museum. We created a 3D data set of the helmet part excavated to form part of the archaeological documentation and conservation records.
Here are some screenshots of the 3D data resulting data set. Measurements can be taken from this file, and the location of different parts of the find such as these coins can be examined in relation to one another. The 3D data set enabled visualisation such as this to be undertaken far more easily than could be done using photography alone.
We mapped an image onto one of the cheek pieces, the area where emperor on horseback is detailed. The taking of measurements is demonstrated here (left). For more images see:

http://www.liverpoolmuseums.org.uk/conservation/technologies/casestudies/3d/romanhelmet/
This wooden nutcracker, mentioned earlier had several areas that were of particular interest to the researchers working on the project studying objects of this type. In those areas of interest we mapped on high resolution images, and the researches added short notes onto the 3D model using freely downloadable software. This image shows a screenshot of a 3D data set created by laser scanning with some high resolution images mapped on in areas of interest. The image just shows the photo labelling, before the notes had been added.

This nutcracker (approximately 250mm in height) was recorded in 3D as a test object as part of the Pre-Hispanic Caribbean Sculptural Arts in Wood Project, led by Joanna Ostapkowicz of National Museums Liverpool.
Researchers from the University of Liverpool were interested in the inscription on this Boundary Stone (left image) found in Wales. You can see that the 3D laser scan (screenshot of the 3D data set seen here on the right), particularly when lit from the side, does show the inscription quite well – this is mainly due to viewing the surface without any colour on it and being able to light it from any angle. These images enabled the researchers in conjunction with other sources to identify what the inscription may have been.
Creating a replica from 3D data; 
Additive processes

The data created by laser scanning can be used to create replica objects. There are two main types of replication process from 3D data of this type – so called “additive processes”, such as for example, selective laser sintering, stereolithography and Z-Corp. (there are many more ) type processes, where the replica object is built up in layers from a powder such as nylon, or plaster by binding it either using a binder or by curing it using a high power laser beam.

The image shown here is a replica skull that has been built in layers from plaster powder bound with an adhesive resin in a process known as Z-Corp. The replica build is complete. It is part-way through being extracted form the build tank, prior to consolidation and hand-finishing.
Creating a replica from 3D data;
Reductive processes

Or alternatively, using so called “reductive processes” such a computer numerically controlled (CNC) machining where the tool path of a milling machine is controlled by the 3D data set. This allows replicas to made from natural materials such as stone. The object being machined here is a Tympanum from above a Norman doorway. See:
http://www.liverpoolmuseums.org.uk/conservation/technologies/casestudies/3d/parwich/

Or for other projects utilising this technology see:

Or
http://www.liverpoolmuseums.org.uk/conservation/technologies/casestudies/3d/calgula/
(contains video footage of 3D scanning and machining in progress)
During recent regeneration, Sheffield City Council awarded the remit to design sculptural planters for Tudor Square, Sheffield to the artist Stephen Broadbent. Using the industrial environment of Sheffield and the natural landscape around the city as inspiration, the artist created sculptures based on natural pebbles and boulders. These hand-made maquettes were one tenth of the size of the final sculptures. From these maquettes, ten sculptural planters have been milled into natural stone. Computer aided design (CAD) modelling based on standard geometries was not appropriate to produce a data set which could be used in the milling process. Instead, a combination of 3D laser scanning, surfacing and digital modelling was used, not only to scale up the maquettes and create a set of files for each planter in blocks of size which could be machined, but also to facilitate later changes in the design to sections of each planter. In this paper we describe the 3D modelling process we undertook on the datasets obtained by laser scanning the artist’s maquettes, and the preparation of the data for 6-axis computer numerically controlled machining.

The images seen here are: Left – screenshot of a 3D data created by laser scanning set of an artist’s maquette. The maquette measured 99mm (H), x 641mm (W) x 462mm (D). Middle – screenshot of the 3D data after scale up (by a factor of 10) and surface re-modelling having been divide into blocks that could be machined into stone, and NURBS surfaced. Right – a sandstone sculptural planter in Sheffield City Centre. The individual blocks that make up the planter were CNC machined from sandstone using the data seen in the image in the middle. The sandstone planter measures approximately 1.3metres (H) x 6.5metres (W) and 4.7metres (D).
The panel, seen here on the left, measuring 10cm (H) x 6cm (W) x 1cm (D) thought to date back to 1340-1360 and belonging to National Museums Liverpool, is one half of the Llandaf diptych: a rare surviving example of a medieval ivory carving from a secular context with a Welsh provenance. The other panel of the diptych was donated to National Museum Wales in 1901. It was only in 2006 that curator Dr Mark Redknap of the Department of Archaeology and Numismatics, National Museums Wales, discovered that these two panels actually matched perfectly and belonged together, as reported in British Archaeology (http://www.britarch.ac.uk/ba/ba95/feat2.shtml).

We laser scanned the left hand panel belonging to National Museums Liverpool and produced a 3D computer model of the carving (seen here in the middle), from which a highly accurate replica panel was cut into a high density polyurethane modelboard using computer-controlled machining (seen here on the right).
The replica panel was then patinated by hand (seen here on the left). Once finished, the replica panel was 're-united' with the right hand panel at National Museum Wales to 'complete' the rare Gothic diptych.

Both of the original diptych panels were on display together at National Museum Cardiff for a year from July 2008. When the original left hand panel returns to Liverpool, the replica will go on display in its place. See:

http://www.liverpoolmuseums.org.uk/conservation/technologies/casestudies/3d/ivorydiptych/
There are many uses of the 3D data for education and display. Here is the skull I showed earlier of Leasowe man part of the only Roman skeleton to be found on Merseyside. A nylon replica of the skull was used to create this facial reconstruction for the exhibition ‘Living with the Romans’ at the former Museum of Liverpool Life. See:
http://www.liverpoolmuseums.org.uk/conservation/technologies/caseudies/3d/romanskull/
And we create many replica objects for use on gallery, such as this square headed Anglo-Saxon brooch.

The images seen here are; Left – a gilded bronze Anglo-Saxon Brooch of dimensions 160mm (H) x 90mm (W) x 15mm (D); middle – a screenshot of a 3D data set created by laser scanning of the brooch; and on the right a gilded bronze replica brooch. See:

http://www.liverpoolmuseums.org.uk/conservation/technologies/casestudies/3d/anglosaxonbrooch/
We are also able to provide interactives for use in educational sessions that accompany our exhibitions, such as here, where we created the possible product of an Egyptian mould.

Amongst the many items on display in the new Ancient Worlds Gallery at World Museum Liverpool are some fragile Egyptian figure-moulds. Figure-moulds were used for making shapes, in this case, of the Egyptian bennu-bird (a heron or phoenix). The carved limestone tablets were made and used in about 664-332 BC. Before the figure-moulds were installed in the gallery in November 2008, we used a Konica Minolta Range 7 close-range 3D laser scanning system to digitally record the surfaces of the moulds to sub-millimetre accuracy create highly accurate 3D computer models of the pieces.
Plaster models of the mould and also of the bird pattern the mould may have created were produced using a 3D (Z-Corp) printer. These replica objects are used by the gallery demonstrators and education facilitators at NML. See:

http://www.liverpoolmuseums.org.uk/conservation/technologies/casestudies/3d/egyptianbirdmoulds/
After that brief overview, we would like to discuss some recent work we undertook on identification and interpreting some objects from the Garstang collection.

The images here are screenshots of 3D data sets created by laser scanning of a Hittite Dice (above), and mould (below). Further information is given on the following slides.
FRANCOISE RUTLAND:

I am currently conducting research into what is known as Garstang’s Hittite Collection in collaboration with the University of Liverpool. This collection is held at the National Museums Liverpool stores. The over-all issues I am addressing are aspects of British colonial self-perception in Liverpool through archaeologists’ collecting methods and the museum’s artefact layout and public presentation spanning from the 1900 until July 1941, when the museum was hit during a WWII blitz.

These rather theoretical aspects however are very much based upon the understanding of Garstang’s Hittite collection which, before 1941 was held within the Aegean & Hittite Gallery on the museum’s ground floor. To start with Professor John Burges Eustace Garstang (1876-1956) originally read mathematics at Oxford; he was born in Blackburn and turned Egyptian archaeologist under Prof. Petrie’s tutelage upon graduation, after spending his academic holidays digging in the UK.

Prof. Garstang established Liverpool’s Institute of archaeology in 1904 and spent various sporadic seasons between 1907 and 1940 excavating in Anatolia, Turkey and the Turkish-Syrian border. It is from here that the majority of the collection originates from. Due to the collecting methods of the time, which basically consisted in chucking whatever one or the native workers’ found on site or at the local bazaar into a box with virtually no labels and certainly no excavation report these artefacts remained a confused jumble. The museum also had little interest in the archaeological details of the individual artefacts and thus it has fallen to me to sort out what’s what after the collections deposition in Liverpool 80 years ago.
The Garstang ‘Hittite’ Dice

It is clearer now that the bulk of Garstang’s “Hittite Collection” is made up of Middle Bronze Age Sumerian seal impressions, pottery, Hittite artefacts from various significant sites in Turkey and Achaemenid burial artefacts as well as a degree of Parthian and Late Iron Age objects. The shoddy labelling and accession information of the time means that many of the objects’ identity is utterly unknown. This process of identification and detailed accession is a significant part of my research which brings us to this 14-sided metal dice. The provenance, apart from North Syria, is unknown, it is not even clear if Garstang dug it up himself or bought it from a dealer. A small accompanying label from 1929 simply describes it as a 14-sided polygon with each side stamped with what might be a seal. Trawling through other museums’ artefact databases has brought up no comparanda and after consultations with a number of curators, university lecturers and other excavation reports the origination or exact use of this object was still unclear. The closest comparative dice are found in 2nd Kingdom Egypt (c. 1200BC). An icosahedron (20-faces) from the Dakhleh Oasis has been discussed by Minas-Nerpal (2007) and suggests that it was used as a Demotic divinatory device to answer questions using an intricate numerical system. However other scholars such as Martin Stadler (2006) disagree. Furthermore these dice are made from pottery with various different symbols painted on each of its 20 sides. Dice have been dug up by Woolley from Ur (now held at the BM), dating from around the same time however they look nothing like this one.

Hittite texts have been translated and they do mention the use of dice in divination and there are various Biblical references to the practice of “casting lots” using dice. Psalm 22 suggests that the practice was very common. This psalm describes life in Israel around the 9th century BC and this would be the same time period during which Uriah the Hittite was besieging Rabbah with the Israeli army under King David’s command. The dice in this image is approximately 2cm in dimension across its widest part.
The symbols on each side were too small and shallow to be distinguished by the naked eye. Since they appeared to be some sort of cuneiform the exact form, depth and spacing of each stroke is significant for correct interpretation of meaning. Furthermore each symbol from each face needed to be viewed side-by-side, obviously impossible when dealing with a 14-sided dice. The method of marking the dice with each symbol is also of significance when identifying the production method used and thus a possible production date. Again the over-all design of each side in relation to each other not only told of production method and dates but also a possible understanding of how the dice was utilised and thus its use.

The interpretation of the markings was down to linguists of ancient languages such as Luwian, Assyrian, Hattic and Hurrian. Due to variations of interpretation more than one linguist was to be consulted. The fact that we had each symbol digitally recorded and enhanced through the 3D scanning meant that we could send off these images to various institutions without the need of the dice ever leaving the NCC premises.
ANNE MARIE LA PENSEE:
To record the dice we used a Konica Minolta R7 laser scanner – seen here.
I have to say that I had low expectations about the results we would obtain by recording the dice in 3D. The dice is very small, the markings are detailed, and the surface is dark and shiny, not brilliant for getting good data from a laser scanner. I still maintain that analysis by light microscopy of the markings would be far better for examining the individual markings, however, it is clear from these images here that the 3D data set, although quite noisy due to the nature of the surface, has shown us some crucial points of interest. Looking at these images, and indeed the 3D object on screen, one can look at the markings in relation one another, as they are located on the dice. One can also see easily that the dice would not have rolled very well - it looks like it could have almost been weighted to fall in certain ways – that or it was badly made – which seems unlikely. I had noticed that the data I collected was exceedingly difficult to register into a coherent 3D model. On closer inspection of images such as this it started to become clear why.
Symbol investigation

• Is the mark the same on all 14 sides?
• Was mark made by same stamp?

When we started to look at the markings in isolation from the dice – something that is easy to do on the 3D images, we noticed that the markings on the square side of the dice fitted better onto the face than those on the triangular sides. This is really odd, but in conjunction with the thoughts I had had whilst registering the data sets together made us look at this a little more closely.
I took the symbol that was best resolved both on the actual dice and on the 3D data set and then set about comparing it with all the other symbols on all the other faces. Here you can see these two faces on the left overlayed in red and green and green in the centre. The image on the right is a deviation map of the two symbols, and the deviation between the two was between -0.15 and +0.2mm. Now even with the error of the scanner, and data alignment of +/- 0.15mm, this is a compelling demonstration that these two symbols are the same.
We repeated this for each face of the dice – here you can see the comparisons between the square faces -
and here with the triangular faces -
Looking at these results one can clearly see that the symbol on all fourteen sides of the dice is the same symbol, and that it was in all likelihood made using the same stamp. The maximum deviation found during these comparisons is +/- 0.3mm.
FRANCOISE RUTLAND
After each image was transposed upon each other it seems apparent that each symbol is identical and was marked on by the same stamp. The inadequate size of the stamp used is mostly apparent upon the triangular sides of the dice, where the stamp overrides the dice edge. An irregular edge was also identified upon one of the longer sides of the mark and this irregularity is identical upon all 14 sides. This close detailed match would not have been possible without the scanner to transpose, enlarge and manipulate each image to be viewed simultaneously for comparative understanding. This result means that each symbol does not hold a particular significance on its own, not in the numerical sense of chance anyway.
Symbol investigation

These images have been sent to Dr Magnus Widell and Prof Anders (both cuneiform linguistics scholars), and this is their understanding: The symbol in the left part of it is outwardly similar to the LITUUS sign. This is a crooked staff, a cross-cultural symbol of authority, which in Anatolia came also to signify wisdom. It is frequent in throughout Syrian and Turkish iconography and as a hieroglyph is used as a determinative for verbs of perception often appearing in various contexts. It seems possible that this was a popular and well known symbol. One might consider the possibility that this object was some sort of lucky amulet, however no other amulets of the sort have been found. And yes dice have been mentioned in various text however none are described as being auspicious in themselves. The identical symbol on all sides and the irregular dice faces have made us entertain the possibility that this could be an early 19th Century fake sold to Garstang (or any other keen archaeologist roaming the region) as a genuine artefact. Furthermore there is the possibility that this was a Roman regional artefact, rather than Hittite. Similar dice in glass have been found at Roman sites. Metal analysis are currently underway to determine metal composition.
Advantages of using 3D scanning

• Non-contact analysis of production methods

• Efficient magnification of markings for interpretation

• Production of eye catching visuals for publication and exhibitions.

The main reasons why 3D scanning was thought to be the best way to investigate this item further was the non-contact, non-destructive analysis properties. Due to the dice’s possible rarity value we did not wish to take any material samples unless there was no other option.

In this case, where the small object held fine nuanced markings we found scanning for interpretation and application purposes quite essential.

The 3D data, both quantitative and imagery, generated by the scanning is now available to use for further research, publications, exhibitions and conferences which allows for further cross-departmental exposure of artefact and analysis methods.
Identification and interpretation;

Case studies from the Garstang collection
- A Hittite mould
This is another artefact from Garstang’s Hittite collection currently at NML’s stores. The granite mould measures approximately 79mm (H) x 141mm (W) x 64mm (D). The provenance, apart from Turkish, is unknown, it is not even clear if Garstang dug it up himself or bought it from a dealer. A small accompanying label from 1929 simply calls it “a stone mould, maybe for votive sandals” festooned with question marks in brackets on either side. Now anyone who is an archaeologist is aware that this is standard practice. When one is unsure of the use of something the label “votive” suddenly crops up and evidence for any type of “votive sandals” anywhere, is still to make an appearance. Trawling through other museums’ artefact databases resulted in no comparanda and after consultations with a number of curators, university lecturers and other excavation reports the use of this object was still unclear.
Non-contact 3D laser scanning

- No artefact *comparanda*
- Rarity value
- No excavation reports or accession labelling
- Use unknown
- Visualisation of mould product with no material assistance is tricky

Since currently no *comparanda* have been found within museums’ artefact databases, both in the UK and abroad, this object now is of significant interest due to its rarity. However since its use, i.e. what is was designed to produce, was unknown not much archaeological context could be produced. As its date was also unknown, very little could be deduced regarding the culture’s technological development and also its cultural provenance. The absence of all this information surrounding this object for all these years only told of Garstang’s and his contemporary curators’ lack of intrinsic archaeological artefact interest.

So the necessity was to find out what the mould was for. 3D laser scanning offered the potential for visualisation, and collaboration between the antiquities and laser technology departments at National Museums Liverpool seemed the best approach for further examination of the mould.
3D laser scanning

• Why is 3D visualisation of the mould of interest?

ANNEMARIE LAPENSEE

Primarily we were interested in how this object was used, that is, what did this mould produce? We envisaged that the digital manipulation of the cavity in particular may be useful in answering this question. Of further interest were the pour hole (or gate), the locating pin holes, the cavity across the bottom of the mould and the striation marks that oddly run across both the cavity and the mould’s parting surface. Once a 3D virtual model of an object exists it can be examined in ways the original can’t. We have found this technique to be particularly useful examining moulds, because a few simple software operations on the 3D digital image allow one to examine the object in ways impossible on the actual artefact. Clearly, examinations on moulds such as this can be performed using putty or plasticine, but this runs the risk of marking or damaging friable surfaces.
Here you can see the digital 3D model. The 3D data set has a resolution of approximately 0.2 mm and a typical accuracy of +/-0.1 mm. Trivial operations in the 3D viewing software can provide useful images for interpretation. A 3D model can be rotated and examined from any angle. Raking light effects can be applied. And, as can been seen here on the right the 3D model can be mirrored to see what a possible other half of the mould may have looked like.
Here is this mirrored image viewed from the top. That this pour hole, the gate, look feasible when mirrored gave us a good indication that the other half of the mould may have been similar to the half we have in our collections. The next stage was to examine the cavity, to try and identify what the mould may have produced. Clearly, at this stage we decided to accept several major assumptions. 1) that we would treat the cavity in isolation to the striation marks that run across both the cavity and the parting surface, and 2) that we would indeed treat the mould as if the other half of it was a mirror image, despite the fact that this would leave a big hole on either side of the mould where, presumably, the molten bronze would run out during casting.
So the cavity was digitally removed from the by trimming away the unwanted data. Whatever object the mould would have produced, would have been the inverse of this cavity, and so the image was reversed – as can be seen here on the right.
This inverted cavity was then mirrored. As we had assumed that the mould’s other half was a mirror of it, and had performed these mirroring operations around an arbitrary plane of symmetry, the distance between the two inverted cavities were too far apart. Once they were moved together so that the edges matched up, the central protruding features overlapped – that is they went through each other. This overlapping data was deleted and we were left with this virtual object seen here on the right. At this point I called Francoise. After one look at this image on the right she knew exactly what she was looking at.
The mould would have been used to make a “duck-billed” fenestrated axe head. The two protruding sections would have indeed met up in the two halves of the mould to create holes on the object. This would have been either to save on the precious bronze, or to make the axe light. The striation marks running across the cavity on onto the mould would have served a dual purpose, the marks on the parting surface act as risers to allow steam and gases to escape during casting, and the marks on the cavity would have created a serrated edge on the axe facilitating the sharpening of the axe blade.
Moreover when you look at this image here on the left, the purpose of the dips on the lower part of the mould become clear. The two halves of the mould would have had a green wood stick inserted in these grooves during casting to make a handle, and would have also had the added benefit of saving on metal. This stick would have sat on the lower part of the protrusion. We created a digital stick to demonstrate this.

3D laser scanning is often used for iconic and important objects, and is perceived as a time consuming and expensive process. Whilst this is undoubtedly true in some cases, in this instance we undertook the scanning, processing and image manipulation in two hours; Making this a feasible method for aiding in the non contact identification of objects of this type. However, what was crucial in this project, as always, was the collaboration between curators, researchers and museums scientists.
Other uses for the 3D data set

- Archiving
- Documentation
- Digital reconstruction
- Replication
- Education
- Gallery interactives

The 3D data set we created of the mould and of the axe it may have created has many uses and applications. One of the many uses of 3D data sets such as that created of the Hittite axe mould is its ability to be used in rapid prototyping technologies. As can be seen here from this resin bound plaster model of both the half mould and the axe. This replica was created using a Z-Corp. 3D printing system which binds plaster powder using an adhesive resin. As mentioned previously, there are many other types of rapid prototyping technologies available utilising a wide variety of different materials and finishes.
FRANCOISE RUTLAND:

When I visited Annemarie for the results I was both impressed and surprisingly disappointed. Certainly very impressed by the imaging results and the level of detail Annemarie had managed to produce from a single scanning but astounded by how well known and obvious the resulting artifact turned out to be. I am an archaeologist by training however I specialized in Near Eastern Early Bronze age burial customs, yet I knew the image to represent a 'fenestrated "duck-bill" axe' produced during Middle - Late Bronze Age Egypt and Syria (1300BC - 1180BC) at first glance. Various axes of this type have been found, though uncommon in Turkey, and one can locate these weapons within various museums’ collections worldwide. They were also quite commonplace during Garstang’s excavations in Egypt and Syria, though none were included within his personal collections.

Thus the scanning results have lead my research onto a new path regarding the unfortunate lack of investigation into the objects themselves and the technological development contexts of the civilisations they were excavated from. This appears to be concrete evidence of an imperial archaeological attitude that one went abroad to bring back plundered souvenirs as curiosities for the lower classes and as an exercise in self-promotion and edification. This development has certainly had a significant effect upon how the rest of the collection and the original gallery display will be approached.
I am currently involved in bringing the original Hittite collection (last on display in 1941) back to life within a new exhibition called “The Hittites are Coming: John Garstang and the Lost Hittite Gallery” to be opened in March 2011 at the newly refurbished Victoria Gallery & Museum in Liverpool. As curators we are now aiming for very different approaches and targets for the visiting public. Access is a target issue, sadly many objects are not to be handled due to their age and value however, thanks to the NCC replicas of the mould and resulting axe will be produced in resin and bronze which will allow us to create a section where we address Hittite metallurgical techniques and weaponry with hands-on experience aimed at both a general adult audience and also to Key Stage 1&2 school groups during our various educational sessions.

Quite apart from the Hittite metallurgical aspects we shall be presenting this process of archaeological artefact discovery from forgotten storage to full understanding through 3D scanning and imaging as a display feature in itself, aiming at creating awareness of the academic and technological methods involved in modern archaeology.

Concluding on a more prosaic note I have to mention that we shall be placing an order of miniature fenestrated axes in bronze to be sold at the Victoria Gallery & Museum shop, which in these cash-strapped times, is not something to be sniffed at!
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