Artist's Case Study – An exploration into the use of 3D scanning and digital processing as a creative tool for digital reconstruction.

1.0 Context

This case study presents a practice-led enquiry into 3D laser scanning and digital processing as a research tool within the context of art and design practice. 3D scanners are becoming increasingly accessible and affordable, making them more widely available to creative practitioners. The starting point of this study was collaboration between the Centre for Fine Print Research (CFPR) PhD candidate Brendan Reid and the ceramist Conor Wilson.

The main focus within Brendan Reid's research project is the application of digital technologies as a creative tool within art and design practice.

Conor Wilson's ceramics have been exhibited nationally and internationally and have recently been selected for **Jerwood Contemporary Makers** 2010. Conor's work is featured in two important, recent surveys on international contemporary ceramics - Breaking the Mould: New Approaches to Ceramics (Black Dog Publishing, 2007) and Contemporary Ceramics, edited by Emmanuel Cooper (Thames & Hudson, 2009). His work focuses on 'ceramics as a discipline as opposed to merely utilizing clay as a material' (Wilson, 2009). In his series of works entitled 'Desire and Control' produced between 1997 and 2005 Wilson created objects which combine qualities of natural form and machine aesthetics, culminating in a series of work which Wilson poetically refers to as 'biomechanomorphic' (Fig 1,). According to Wilson one of the essential characteristics of ceramics 'is the combination of form and decorated surface. This makes it an ideal discipline within which to explore the conjunction of traditional, haptic technologies and new, computer-aided technologies'. As the name of the series of work implies, 'Desire and Control' seeks to hand over a certain amount of control of the objects creation. This open minded approach from Wilson led to an opportunity for a collaborative project between Conor and the Centre for Fine Print Research. Just as Wilson had previously been interested in the combination of natural forms and machine aesthetics, the use of digital processes was seen as an extension of this mode of thinking. This allowed for an approach within this research which combined natural forms with digital aesthetics through the use of 3D scanning and digital processing software.

Fig, 1 Temenos (2003) (28 x 20 x 11 cm) (Variable edition of 12)   Cockscomb II (2007) (20 x 33 x 18 cm) (Variable edition of 12)

2.0 3D Scanning Technical Background

3D scanners can be divided into two main types contact and non contact scanners.

2.1 Contact Scanners

Contact 3D scanners probe the subject through physical touch. A CMM (coordinate measuring machine) is an example of a contact 3D scanner. It is used mostly in manufacturing and can be very precise. The disadvantage of CMMs though, is that it requires contact with the object being scanned. Thus, the act of scanning the object might modify or damage it. This fact is very significant when scanning delicate or valuable objects such as historical artifacts. The other disadvantage of CMMs is that they are relatively slow compared to the other scanning methods. Physically moving the arm that the probe is mounted on can be very slow and the fastest CMM's can only operate on a few hundred hertz. In contrast, an optical system like a laser scanner can operate from 10 to 500 kHz. Other examples are the hand driven touch probes used to digitize clay models in computer animation industry.

2.2 Non-Contact 3D Scanners

Non-contact 3D scanners are very analogous to cameras. Like cameras, they have a cone-like field of view, and like cameras, they can only collect information about surfaces that are not obscured. While a camera collects color information about surfaces within its field of view, 3D scanners collect distance information about surfaces within its field of view. The "picture" produced by a 3D scanner describes the distance to a surface at each point in the picture. Both of these scanners create a 3D image through triangulation: a laser or light dot, line or pattern is projected onto the surface of an object from a hand-held device and a sensor (typically a charge-coupled device or position sensitive device) measures the distance to the surface. Data is collected in relation to an internal coordinate system. Within this case study two types of non-contact scanners have been used: a handheld laser scanner and a structured light scanner (fig, 2).

Fig, 2 Atos III white light scanner (courtesy of www.gom.com) Zscan handheld scanner

2.2.1 Hand-held Laser Scanner

Laser scanning technology consists of using lasers to project onto the object one or more sharp stripes. Simultaneously, light sensors acquire the scene and by applying simple geometrical rules the surface of the object is measured. To assure the inoffensiveness of the light beam, only eye-safe lasers are used. Special optical systems and mirrors are used for the generation of stripes from a single laser light beam. The laser scanner unit, which is composed of the laser, the optical system and the light sensor, is moved across the human body to digitize the surface. As the handheld scanner is portable and therefore is in motion the position of the scanner must be determined. The position can be determined by the scanner using reference features on the surface being scanned, typically adhesive reflective tabs.

2.2.2 Structured Light Scanner

Another technology used extensively for scanning is based on the projection of light patterns and is commonly referred to as ‘white light scanning’. In contrast to laser scanning, instead of moving a single (or multiple) laser line over the object, a light pattern (usually in form of stripes) is projected onto the object. The scanning device is composed usually of a single white light projector and a single camera. More complex systems use multiple cameras and projectors. The measurement process is similar to the method of laser scanning: stripes on the surface are measured singularly by using triangulation. Usually, binary coding systems are used to determine the origin of the single stripes; for the increment of the resolution, the projected stripes are additionally shifted.

3.0 Current approaches to 3D scanning

Many current approaches utilize 3D scanning as a method of reproduction, replication and documentation. These devices are used extensively by the entertainment industry in the production of movies and within cultural heritage for the documentation of cultural artifacts.

Within culture heritage there have been many research projects undertaken to scan historical sites and artifacts. In 1999, two different research groups started scanning Michelangelo's statues. Stanford University with a group led by Marc Levoy used a custom laser triangulation scanner built by Cyberware to scan Michelangelo’s David. The scans produced a data point density of one sample per 0.25mm, detailed enough to see Michelangelo’s chisel marks. These detailed scans produced a huge amount of data (up to 32 gigabytes) and processing the data from his scans took 5 months. The motivation of the ‘Michelangelo Project’ according to the Stanford University website is “to advance the technology of 3D scanning, to place this technology in the service of the humanities, and to create a long-term digital archive of some important cultural artifacts”.

The Michelangelo Project used custom built scanners, at the top end of there technical capabilities. A myriad of scanning projects within cultural heritage have been undertaken worldwide within the last ten years. The Stanford University project, now over ten years old is still a seminal achievement within the history of digital scanning (fig, 3).

fig, 3 Digital Michelangelo Project, example of 3D scanning within cultural heritage, digital scan and model created from digital scan

4.0 Part 1: Creative development: data acquisition using 3D scanning

Whilst the use of 3D scanning is well know from the perspective of cultural heritage applications less is know within art and design practice. According to the architect William J. Mitchell the use of digital technologies can be divided into two approaches *pre rational and post rational* (Mitchell, 2003). A pre rational approach is used when the specific outcome is clearly defined. For example the use of 3D scanning within cultural heritage outlined above has a set goal of accuracy as a process of documentation. A post rational approach suggests less clearly defined outcomes and in many ways is more akin to intuitive approaches within creative practice. These two approaches are expressions of different approaches to creative making and neither has precedence over the other. In many cases a mixed approach is beneficial in relation to digital design. For the purpose of this collaboration a mix approach was adopted. A pre rational approach was utilized for the data acquisition (3D scanning) stage of the collaboration. Through a dialogue with the artist the initial approach of the investigation began to emerge**.** The first step was to use 3D scanning as a process to transfer 'real world objects' into 'virtual space'. After further discussion with the artist an appropriate object was selected as a starting point (fig.). One of the questions raised by the artist was, 'How can the scanner deal with the sharp edges of the object?' LemonSqueezer was selected because of its specific formal characteristics, a combination of curved surfaces and sharp edges. Both of these characteristics are interesting from the perspective of 3D scanning. Although scanners can easily scan flat surfaces, edges can sometimes be more of a challenge. One of the limitations of 3D scanning is reflective shiny surfaces. Therefore in order to assist in the scanning process an unglazed blank matt white version of 'LemonSqueezer' was used (fig, 4).

Fig, 4 LemonSqueezer, Conor Wilson 1997

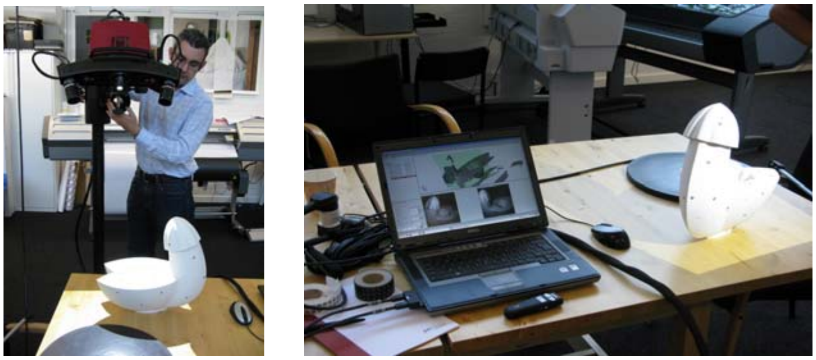
Unglazed 'LemonSqueezer'

4.1 Procedure

The first procedure was to utilize 3D scanning as a method to transfer information of physical objects into virtual space.

4.2 Action: 3D scanning using Atos III white light scanner

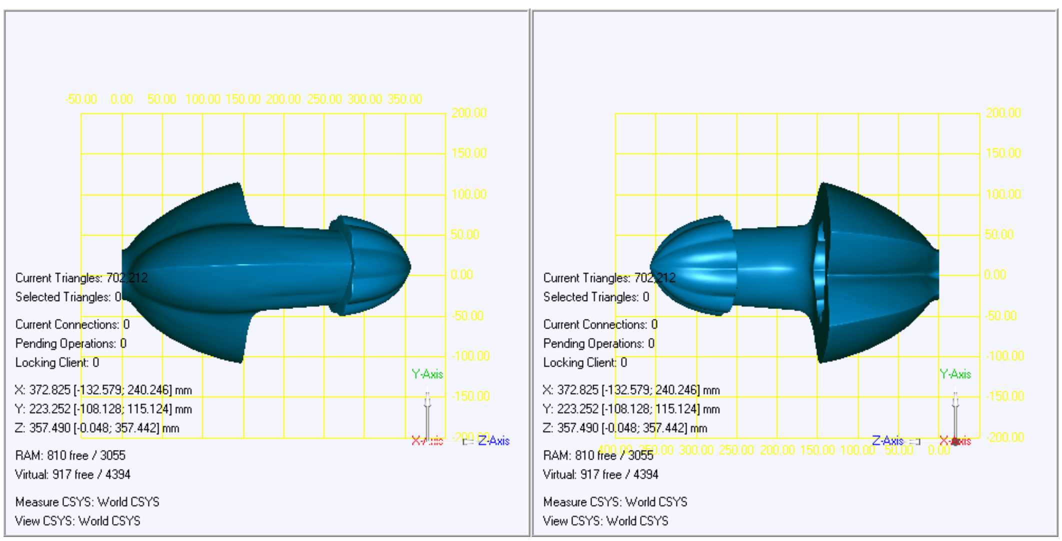
The Atos III scanner, supplied by GOM optical measuring techniques was used as a benchmark for digital reproduction. ATOS is a non-contact white light 3D. White light scanning is a very fast and accurate non-contact method of obtaining a digital 3D model. This means aerospace companies have tested the system to certify the accuracy of its measurements and inspection analysis to incorporate it into their processes. ATOS utilizes two high resolution cameras and a projector. By shooting a fringe pattern onto the part's surface it automatically obtains data over a full volumetric field. ATOS measures an entire area of the part's surface rather than point-to-point measurements (GOM, 2010). Since it uses white light technology the scan time is very fast. With the ATOS III, a single measurement is taken in less than one second. This flexible optical measuring machine is based on the principle of triangulation (GOM, 2010). Projected patterns are observed with two cameras. 3D coordinates for each camera pixel are calculated with high precision, a polygon mesh of the object's surface is generated (fig, 5).

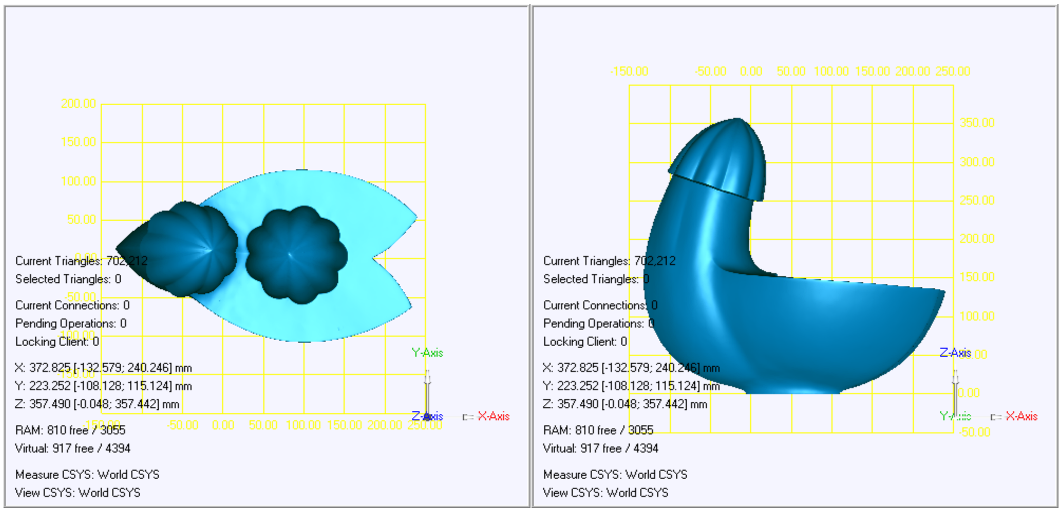


fig, 5 scanning the sculpture with Atos III, images courtesy of www.gom.com

4.3 Results

The ‘Atos’ ranges of scanners are at the high end of digital scanning. ATOS III is a digitizer that is based on camera technology developed by GOM with the ability to deliver 4 million data points in each measurement. The strength of this system is its high resolution and speed. For the purpose of this case study this scan was used as a benchmark for digital scanning (fig, 6).





Fig, 6 Final scans, images courtesy of www.gom.com

5.0 Current limitations.

In the fields of computer graphics and computer-aided design (CAD), advanced modeling systems such as Rhino, Solidworks and Autodesk Maya have made possible the design of highly detailed models. However, it is still difficult with these systems to directly create organic shapes such as human faces or freeform surfaces such as natural organic forms. Creating freeform surfaces is a challenging task even with advanced geometric modeling systems. 3D scanners offers alternative approaches for data acquisition. The 3D scanning of existing objects or clay maquettes allows real-world objects to be transferred into virtual environments through a process of digitization. The collected data is referred to as a ‘point cloud’. The problem of converting this point cloud produced by laser scanners into useful geometric models is referred to as surface *reconstruction*.
Through a process of triangulation the scanning software converts the collected data into a digital surface. Many different technologies can be used to build these 3D scanning devices; each technology comes with its own limitations, advantages and costs. It should be remembered that many limitations in the kind of objects that can be digitized are still present: for example optical technologies encounter many difficulties with shiny, mirroring or transparent objects. There is however methods for scanning shiny objects, such as covering them with a thin layer of white powder that will help more light photons to reflect back to the scanner. A white surface will reflect lots of light and a black surface will reflect only a small amount of light. Another limitation of 3D scanning is the

construction of edges. Whilst the creation of point cloud data works well for the acquisition of smooth curved surfaces, difficulties arise when trying to digitize sharp corners and edges. Point cloud data have difficulty in defining edges because the points gathered are arranged in a grid pattern and cannot be placed specifically on the peaks or edges of an object. This limitation becomes more apparent when sharp edges are required for example in mold making processes. Although the Atos scans gave extremely high resolution results and accurate data another approach was taken to test out the possibility of sharpening the edges of the object.

5.1 Alternative approaches

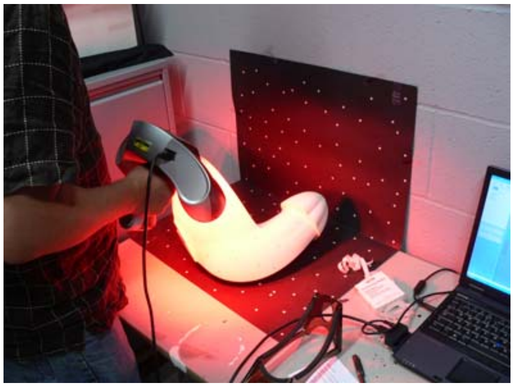
Insights were gained from an approach taken within the area of digital mold making. One possible solution was designed by Reynald Chaput, owner of Ideas in 3D. Chaput distinguishes between different approaches employed to digitize objects within cultural heritage and for mass production, stating “The movie industry digitizing requirements and the manufacturing industry requirements are totally different from one another. One of the main differences is that in the manufacturing arena, you must have absolute control over the edges to be digitized and laser or scanned digitizing can never put points exactly on the edges” (Chaput, 2010). Reminding us that fast point clouds are not always the only requirement, ten years ago Chaput decided to combine non contact and contact approaches. His company built their own scanner specifically designed for edges. The READ (Reverse Engineering and Digitizing) system has a manual probe with a laser that constantly recalibrates the probe’s exact position. This combines the strength of both contact and non contact scanners and allows for accuracy when dealing with object edges.

6.0 Part 2: Creative development and realization using handheld 3D Laser Scanner and Geomagics reverse engineering software.

The second approach builds on insights gained from Chaput’s approach. Instead of using contact and non contact scanning this approach utilizes a non contact scanner (Zscan 700) and a reverse engineering software package (Geomagics Studio software). The reverse engineering software replaces the need for contact scanning hardware as the edge of the object can be digitally reconstructed within the software. Although this approaches would not offer the accuracy required for mold making it was felt that the tolerance levels would be acceptable within an art and design context.

6.1 Procedure

The first stage of the procedure is the acquisition of data. In order for the handheld scanner to be portable a series of target dots are attached to the surface of the object and a dotted background is used. This allows the object to be positioned in three dimensional spaces, similar to GPS in satellite navigation systems. Then a series of scans are taken from different angles to capture the surface geometry (fig, 7). Data is collected within three dimensional spaces by the computer and recorded as data points, called ‘point clouds'. The point clouds produced by 3D scanners can be used directly for measurement and visualization within a variety of disciplines, however most 3D processing software require the information to be in the form of polygonal 3D models or NURBS surface models. The most common file type for 3D processing and printing is a stereo lithography format (.stl). A series of object views are scanned. The aim is to create enough individual scans that can then be stitched together to create a whole object.



Fig, 7 object with registration dots

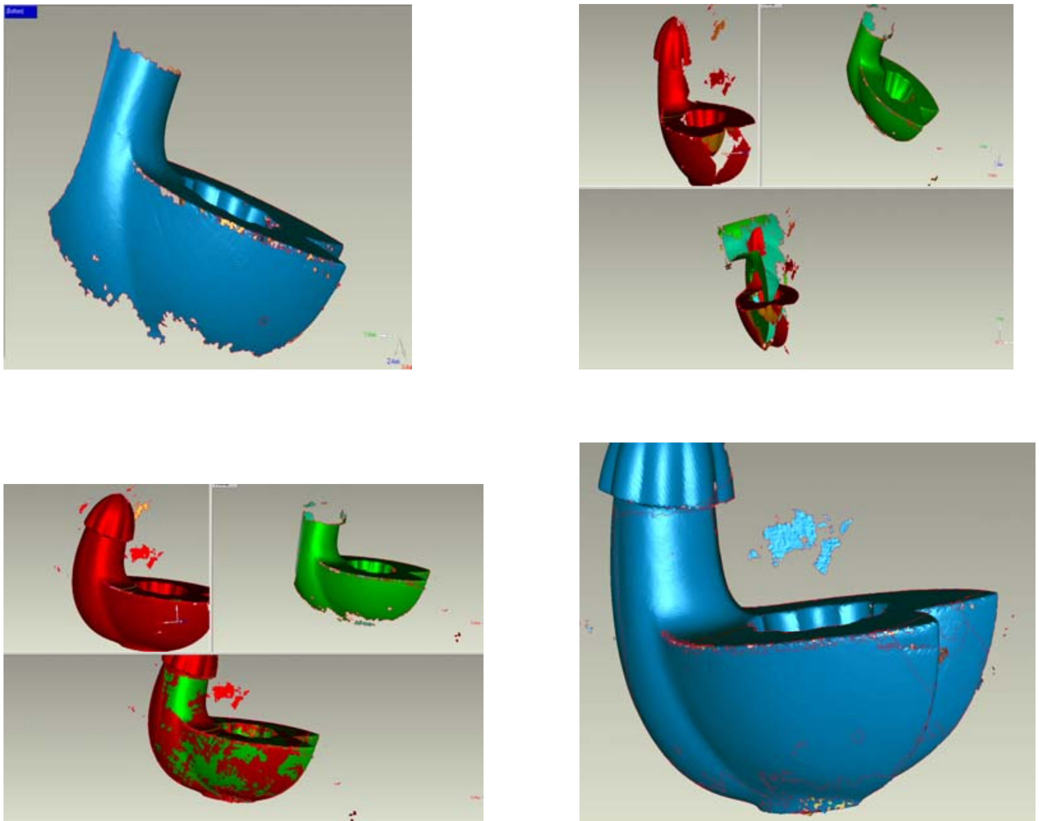
scanning the object using the handheld laser scanner

6.2 Action

Once the individual scans have been completed a series of operations are required to create a complete object with a continuous surface. These stages include merging, hole filling and cleaning the object. A range of stand alone software programs are available for this procedure. For the purpose of this case study 'Geomagics' reverse engineering software was used.

6.3 Merging

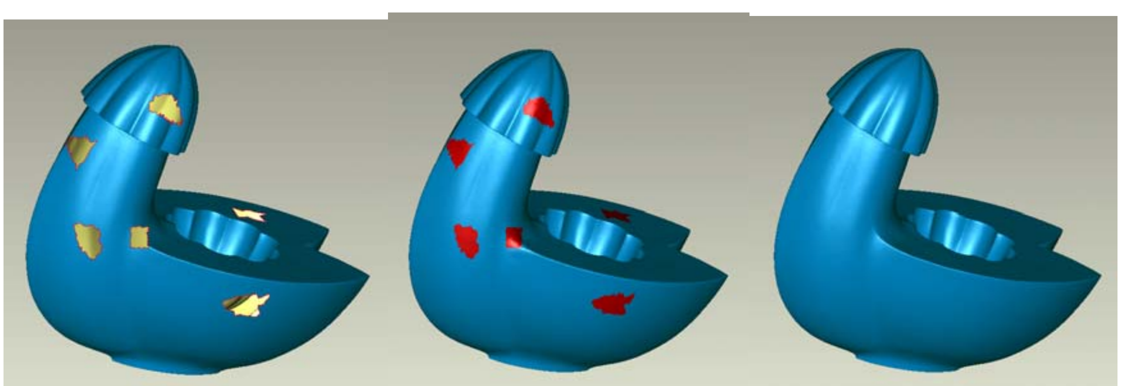
The next stage in the process is merging the various scans to create a complete object. This software allows all the scans to be 'stitched' together through a manual process of registration. Then the stitched scans can be merged together to create a continuous object (fig, 8).



Fig, 8 merging scans in Geomagics

6.4 Filling holes

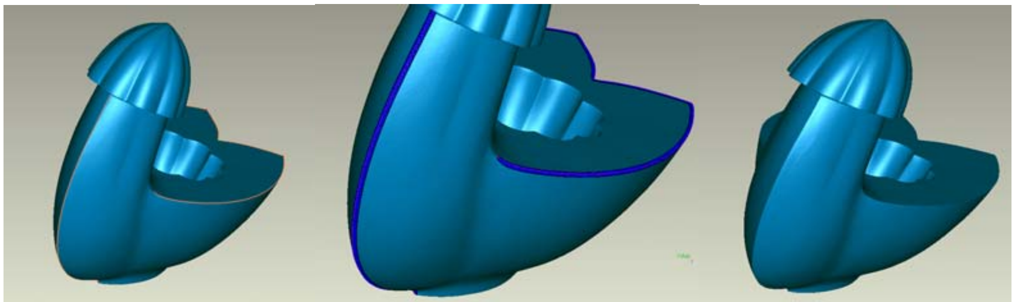
Even with scans from a variety of angles not every part of the surface may be recorded. Geomagics software offers both automatic and manual options for filling holes (fig, 9).



Fig, 9 hole filling in Geomagics

6.5 Sharpening edges

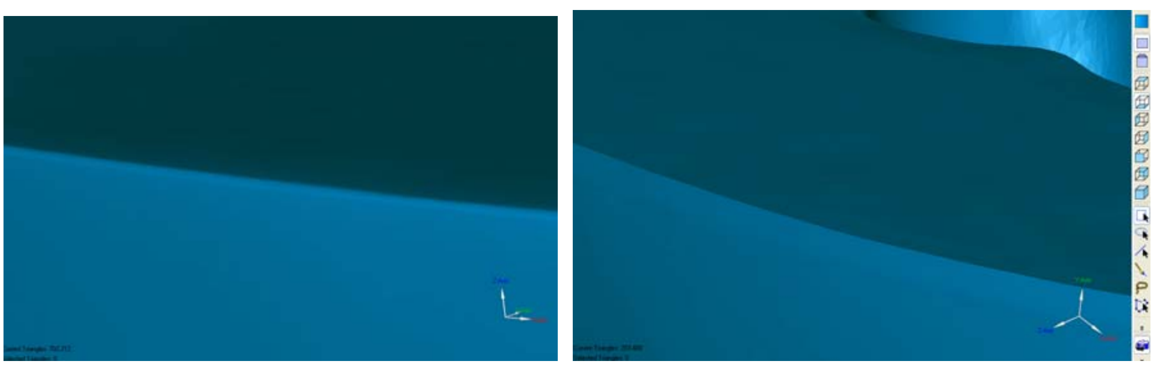
When all the operations are complete an object is created which has a continuous closed surface. The final stage of the process relates to the original question ask by the artist, how can the edges of the object be sharpened? (fig, 10).



Fig, 10   selecting edges   sharpening edges   sharpened edges

6.6 Result

Through a combination of 3D scanning and digital software it was not only possible to scan the object surface but through the use of a series of procedures it was also possible to construct an object with sharpened edges (fig, 11).



fig, 11 comparison of scanned edge with edge that has been reconstructed within the software

7.0 Part 3: Development: mapping 2D images onto 3D surfaces

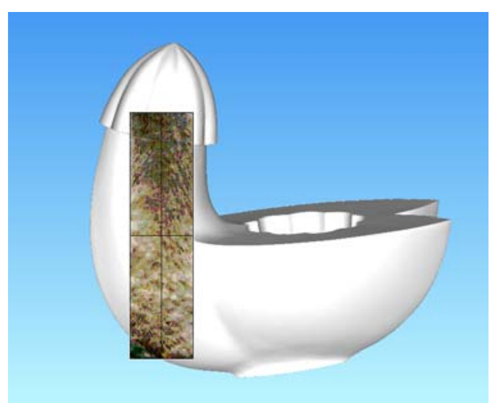
Building on Mitchell's discussion of pre-rational and post-rational thinking this section of the case study documents a post-rational approach to the use of digital processing. Whilst the use of 3D scanning and processing methods within areas such as cultural heritage adopt a pre-rational approaches, the aim being documentation and accurate replication. Following on from Wilson's initial open-ended approach to the collaboration a more heuristic approach was adopted. The central aspect adopting a process that allows for variation and construction rather than replication. Further discussion with the artist led to selection of a series of 2D images that would be mapped onto the sculptural surface. One of the inspirations for the original sculpture was the shape of a swan. As stated in an email by the artist 'I had a better idea - swan's feathers! Playing with the birdiness of the thing' (Wilson, 2010). A series of images were gathered by the artist (fig, 12) and the next stage was preparation of the images and the mapping of these images on to the objects.

Fig, 12 original images of feathers taken by the artist, the red colour represents a swan beak

7.1 Procedure

The first stage of the procedure was the transformation of the images in Photoshop software. This involved the adjustment of the contrast and curve levels of the files (fig, 13). The files were then imported into Zedit software. The image was then virtually overlaid and wrapped onto the surface of the 3D object.

fig, 13 image contrast transformed in photoshop



fig, mapping images in Zedit

7.2 Result

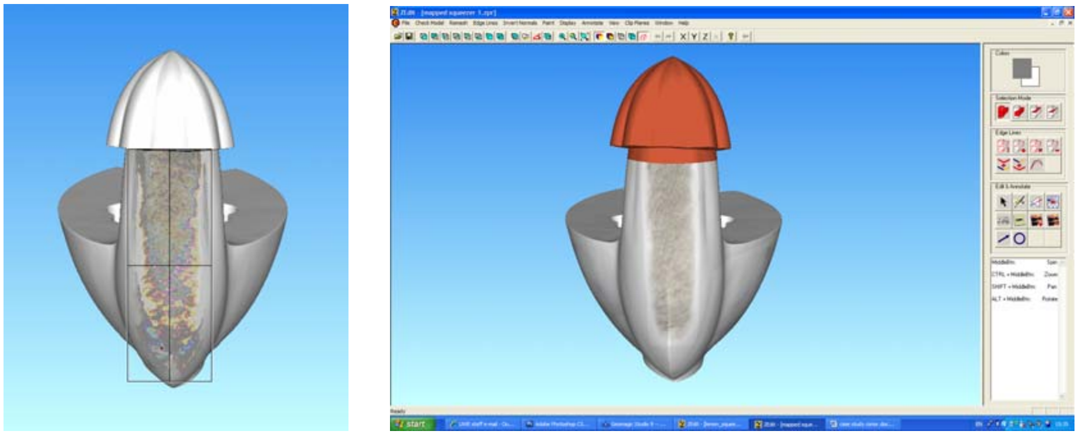
One of the main weaknesses of the resulting test revealed that the images were difficult to map and merge resulting in a crude collage effect (fig, 14). Although this may be useful aesthetic depending on the intention of the artist, after further collaboration it was decided once again to modify the images within Photoshop software.

fig, 14 initial result of mapping object

7.3 Actions

To refine the mapping qualities of the images a variety of Photoshop tools were used to transform the image. fade the hard edges of images and to create white borders to enable the images to merge more seamlessly (fig, 15). The files were then exported back into Zedit to be re-mapped onto the object. Once the files were modified in Photoshop they were then imported into Zedit software (fig, 16).

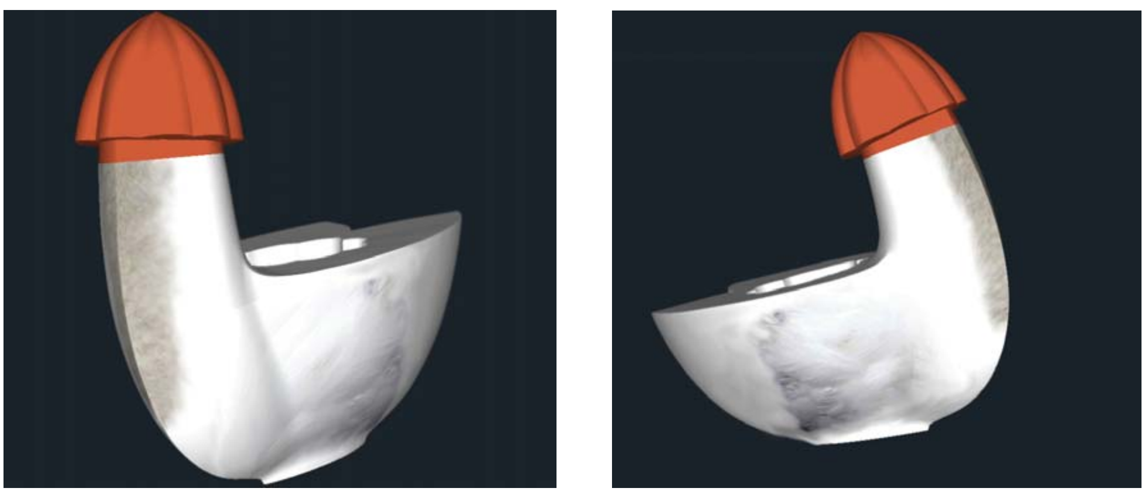
fig, 15 images edges faded and refined in Photoshop



fig, 16 image mapping using Zedit software

7.4 Result

The results of this procedure allowed for a more continuous merging of the imagery. This fitted with the subtle qualities of the swan's feathers. The flat red colour was wrapped 360 degrees around the top section of the object to imply the qualities of a swan's beak (fig, 17).



fig, 17 swan feather images mapped onto object

7.5 Conclusion

The cost of digital scanning has fallen since the Michelangelo project, according to Moore’s Law the cost of technology falls by half its price every eighteen months. Therefore as these technologies are becoming more widely available it opens up the possibility of using the scanner as a creative tool within the context of art and design. Unlike its use within cultural heritage, were its main use is as a documentation and replication tool, within art and design practice there is potential for 3D scanning as a starting point within a post-rational approach. However although this case study did not seek to use the scanner to merely replicate the object, it was felt that it was an interesting object to try and reproduce as accurately as possible (at the scanning stage) due to the combination of curved surfaces and sharp edges. The initial approach was to test out the use the three selected methods of scanning to digitize the object. In order to scan an object successfully the object has to be either of a light matt surface or be treated with a special white powder which dulls down the object surface. As the scanners gather information about the surface geometry it is currently not possible to scan transparent objects unless they have been coated. Also reflective shiny surfaces make it difficult for the scanner to triangulate the data. An unglazed version of ‘LemonSqueezer’ was used as a base object. The ceramic matt white surface was ideal for scanning (fig)
It is anticipated that many more creative collaborations will be explored as 3D scanning receives increased exposure through the dissemination of research and innovative approaches within art and design practice. Such collaboration offers the potential for exploration that is beyond the scope of one discipline. Creating what Parsons and Campbell (2004) refer to as a “complex and multifaceted decision points” for researchers, technicians and artists. As the role of digital tools offers new modes of thinking, it also encourages new approaches to design (Cross, 1984). Most notably for 3D scanning and processing the ability to adopt post-rational approaches that can expand on many current reproduction methods and allow for variation through a combination of methods which allow for reconstruction.

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