A 3D Print of the Choragic Monument of Lysicrates

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3D Printing for International Exhibition

In 2010 Dr. Cawthorne was commissioned by an American / Greek client consortium to produce a highly detailed digital reconstruction and 3D print of the 4th century BC Choragic Monument of Lysicrates in Athens. Drawings by the 18th century architects James Stuart and Nicholas Revett were used as the basis of the reconstruction since much of the detail on the actual monument has been lost in the intervening 250 years.

A number of versions of this reconstruction were required for various exhibition and fabrication purposes and required innovative internal structural design and lightening to allow such a large 3D print in resin bonded gypsum powder to bear its own weight. As part of this process an innovative post production surface treatment was developed to greatly increase both the hardness of the material and yield a very even and lustrous bright white finish, reminiscent of the pentelic marble from which many parts of the original monument were created.

Further innovative techniques were developed to digitally convert the complex 2D drawings of the circular frieze around the entablature of the monument into full 3D relief. Although not the largest produced by the group (components for a two meter high version in the US were produced for slip casting) a 1:20 scale direct print version was selected as a centerpiece exhibit by the Royal Scottish Academy in Edinburgh for their Open Exhibition in November – December 2010.
The Monument and its History

This fourth century BC classical Greek monument built in Athens to commemorate a victory in a singing competition is famous both for its very early use of a Corinthian order and its frieze of sculptures depicting episodes from the myth of Dionysus. It was carefully surveyed by the British architects James ‘Athenian’ Stuart and Nicholas Revett as long ago as 1751 and they published the first measured drawings of it in their ‘Antiquities of Athens’, in London in 1762. Their work on this and other ancient sites in the Levant for the first time provided highly accurate scale drawings which allowed British architects to develop a stylistically and technically authentic Neo-Greek form of classicism distinct from the Roman forms which had been used previously. Because of this the Choragic Monument of Lysicrates is historically significant in the development of architecture in Britain, Europe and the United States in the 18th and 19th centuries. Several direct copies or adaptations were built for instance at Shugborough House, Tatton Park, two in Edinburgh, one in Alloway and overseas at the Carnegie Museum of Art in New York, in Nashville Tennessee and another in Sydney Australia. Important as it was then in terms of architectural influence, it was the process and outcomes of meticulous measurement, drawing and publication that Stuart and Revett demonstrated for the first time and which arose from methodologies then being developed in early archaeology and military surveying that were to become important today. Since the mid 18th century the monument has been badly damaged by careless building work, war and more recently by atmospheric pollution. Much detail has been lost leaving Stuart and Revett’s highly detailed and authentic drawings as the best surviving representations of the complete monument.
Experiencing the Freize in 3D

Because of these degradations one of the difficulties with the Choragic Monument as it exists today is that it’s impossible to fully appreciate the symbolism and cultural messages that it was intended to convey. Much of the sculptural iconography is now absent or so badly eroded that it is illegible. A good example of this is the frieze which in low sculptural relief depicted the myth of Dionysus and the pirates. This is now extremely difficult to decipher because of damage and erosion. Moreover like the monument as whole the frieze was designed to be seen “in the round”. By walking around the monument the story would “play” as a visual narrative. This process of movement and “reading” cannot of course be conveyed by the two dimensional drawings and because of the illegibility of the original it can now no longer be conveyed by the monument itself. For these reasons a research project was undertaken to assess the feasibility of producing a 3D printed model of sufficient size, detail and accuracy to be able to meaningfully and authentically convey this lost experience of “reading” the monument and its sculptural narrative and symbolism by once more being able to walk around a model of it with this detail fully legible. One of the first challenges of doing this was to convert Stuart and Revett’s 18th century engravings into 3D relief sculpture on a cylindrical surface such that they were suitable for 3D printing. This was achieved using a novel adaptation of specialized 3D printing software to extrude 2D figures derived from scans of the etchings to predetermined heights based upon their 2D grayscale tone value. These extrusions were then digitally “wrapped” by point mapping around the cylindrical frieze drum of the monument. The resulting low relief digital sculptures exactly recreate the forms depicted by Stuart and Revett.
Engineering a Large 3D Print

Selecting a suitable medium for 3D printing required several strategic choices to be made which had engineering implications. In order for the detail of the monument to be sufficiently legible in 3D as one moved around it, the model itself had to be relatively large. Through a series of trial prints with details it was found that the minimum size at which the detail would be legible was 1:20 scale, producing a model which was over two feet in height. By the standards of the time this was a very large 3D print that would require a considerable volume of print material and irrespective of the process used would need to be made in several sections. Cost was a significant factor meaning the most economic alternative was 3D printing in powdered, resin bonded gypsum. This a relatively soft, heavy material that has a low tensile strength and in large volumes similar to those needed for the model becomes compressible under its own weight. To minimize structural distortion of the model a high degree of hollowing and optimization of the internal structure and wall thicknesses was carried out, parts being adjusted to take more loading at the base of the model than at the top. Interstices were introduced not only to reduce weight and material used but also to allow draining of the unused gypsum powder residue when the components had been printed. Locating tenons and lips were also introduced to ensure precise and correct alignment of the components and to mask the joints between them. Finally once the parts had been printed a special, lacquer based impregnation treatment specifically developed for this project was applied to harden the components to give resistance to abrasion, more compressive and tensile strength and a lustrous bright white finish which sharpens the appearance of details.

Trial components from the 3D print, note the interstices, and drain holes to reduce weight, optimise structural strength and allow removal of unused print material.
Derivative 2.5m High Plaster Model

The 3D digital model from which this 1:20 physical print was produced was used to create parts for a much larger 1:5 scale version of the monument built by Timothy Richards Model Makers in Bath. This derivative model built in cast plaster was over two and half meters high and the authors (Cawthorne & Davies) produced 3D prints of key components which Timothy Richards Model Makers then used to create flexible silicone rubber moulds from which multiple plaster copies were produced. These plaster copies were then assembled upon an armature structure to make the complete large scale model.

As far as is known this was the first time that 3D printing had been used in this way to create cast plaster architectural components of significant size. The process was entirely successful and demonstrated in a Proof of Principle (PoP) study that manufacture of large architectural cast plaster decoration and sculpture using 3D printing of resin bonded gypsum powder was economically and technically feasible.

This derivative plaster model was exported to the US in April 2010 and exhibited at the University of Notre Dame in Indiana as the centerpiece of the prestigious international Driehouse Prize in Architecture awards ceremony and exhibition. There it was possible to re-examine the original intention of creating a reconstruction of the Choragic monument large enough to fully appreciate the symbolism and cultural messages that the monument was intended to convey, particularly the narrative of the Dionysian frieze. In this it was entirely successful.
Public Exhibition

Widely regarded as being the largest 3D print made at that time in the UK the finished 1:20 scale direct 3D printed model of the Choragic Monument of Lysicrates was selected through peer review by the committee of the Royal Scottish Academy for exhibition at their 2010 Open Exhibition in Edinburgh in November of that year. It was viewed by over eight thousand visitors during the four weeks that it was on display. It has also been shown at other events around the UK including events hosted by the AHRC in their Connected Communities programme in 2013.

As is noted above, the 3D digital model from which this physical print was produced was used to create parts for a much larger version of the monument made in plaster by Timothy Richard Model Makers in Bath, UK. The 3D printed mould parts of key complex details were produced by the authors. This derivate model was exhibited at the University of Notre Dame in US as the centerpiece of the prestigious international Driehouse Prize in Architecture whose past recipients have included Robert Graves Michael Stern Alan Greenberg, Andres Duany, Quinlan Terry and Leon Krier. As such the author’s work has received public and peer review by exhibition at the highest level in the international art and architecture community being selected for presentation at these world leading exhibitions. The project has demonstrated that careful use of novel digital technologies can assist in the public understanding and appreciation of world architectural heritage in an approach which had previously not been appreciated.
Image of the 3D computer model from which the physical 3D models and components were printed.