Abstract
After over 100 years of continuous display outdoors, the stoneware sculpture *Flower in the Crannied Wall*, commissioned by Frank Lloyd Wright from the artist Richard Bock, was brought inside. The move followed conservation treatment by the Midwest Art Conservation Center (MACC) in Minneapolis, Minnesota to repair structural damage.

As part of this treatment, and in order to preserve Wright’s vision of Taliesin as it was at his death, a reproduction of the sculpture is being created for permanent display in the outdoor location. 3D laser scanning and a combination of 3D printing and milling are being used for the reproduction, the installation of which is anticipated in September 2014. This paper discusses the techniques used.

Introduction
In 1909 Frank Lloyd Wright commissioned a sculpture that was completed by Richard Bock for the Dana House in Chicago. Two years later, Bock produced a second cast of the same work for Taliesin, Wright’s estate in Wisconsin.

The sculpture, which depicts a standing female figure emerging from a crystalline obelisk, has been called the keystone of the Wright Style and was on display in various outdoor sites on the estate for 102 years, until it was deinstalled for conservation in 2013.

On the flat plane of the back surface are inscribed the words of Alfred Lord Tennyson’s poem (1869) from which the artwork gets its name, spacing as on the sculpture:

Flower in the Crannied wall
I pluck you out
Of the crannies
I hold you here
Root and all in my Hand
Little flower
But if I could Understand
What you are
Root and all
And all in all
I should know
What God
And man is

Why Scanning?
3D scanning was chosen to reproduce *Flower* both for ease-of-use and safety. Extricating a mold from the surface, particularly in the detailed undercut areas of the head and crystal, would have risked damage to the sculpture. Additionally, making a mold would have required moving the sculpture from the secure location of the conservation lab to an off-site workshop, presenting the physical risks of movement as well as increased vulnerability to theft or vandalism.

Scanning also provides an opportunity for wider accessibility to the sculpture’s form. The scanned files are the property of the Frank Lloyd Wright Foundation, as stipulated in the treatment proposal, and can be used for a variety of purposes of their design and choosing. Possible examples include creating an educational web element, exploring interactive programming onsite, or printing smaller-scale reproductions for sale. In the event that anything should happen to the original or its reproduction, a digital record now exists; this information can be shared easily and used for as long as the software exists to manipulate it.
In Progress: 3D Laser Scanning and Reproduction of Taliesin’s *Flower in the Crannied Wall*, continued

**Procedure**

Scanning was completed by outside contractor First Article Corporation using a Konica Minolta Range 7 Non-Contact 3D Digitizer, which they brought to the MACC Objects Lab. The scanning took approximately 3 hours and required recalibrating the scanner once to compensate for a subtle temperature drop in the lab. High resolution scans were completed for the text panel on the back. After scanning, First Article produced watertight Stereo Lithography (STL) files of maximum size, with no compression. There were two files, one of the overall sculpture and one detail of the text.

Small clay dots placed on the sculpture enabled the different scans to be keyed together.

The goal of the printing/milling was to create an actual-size positive model of the sculpture from which a mold could be taken. Due to the size of the sculpture it was necessary to produce this model in several pieces. Since there are large flat planes and areas of the sculpture that do not have extensive surface detail, most of the model was cut on a milling machine with only the details of the head, front crystal, and back text panel printed out on the 3D printer.

To do the milling, the STL files were brought into the router’s computer and viewed with Solid View software for manipulation and slicing. The advantage of this particular software is that it can cut the data, creating separate files for the head and body for example, while retaining the watertight STL format of both sections. Once the scan had been divided into 27 smaller separate sections, they were prepared for milling and printing.

The milling machine used was a Techno LC Series Computer Numerically Controlled (CNC) Router with Cut 3D software. This software enabled manipulation of the scan in space so that it could be positioned optimally for cutting and adjustment of the scale so the pieces fit together correctly and emerged the right size. Also, since the router cut in 2-inch slices, this software sliced each scan (already cut down from the main file) into 2-inch sections.

The pieces were cut into polyurethane sign board, which provided a nice toothy texture similar to that of the original sculpture. The cuts were first roughed out with 0.25” ball nose bits using a 27% step-over (the distance the bit moves from one cut to the next). After roughing out, the finishing tool pass was made with 0.125” ball nose bits and a 4% step-over. The roughing out pass was made along the y-axis, while the finishing pass was made along the z-axis to erase stepping lines.

Meanwhile, the head, crystal, and text were printed out on the ZCorp ZPrinter 150 3D printer using the ZPrint software. This printer has a 9” x 9” x 9” size limitation. It prints in gypsum which it lays down one line at a time, much like a 2-dimensional ink-jet printer.

Next, the STL files were transferred to the 3D shop at the Minneapolis College of Art and Design (MCAD), where the reproduction is being fabricated. The scans were examined for polygon resolution to determine that they were dense enough with no gaps or thin areas of data. The more data, the more likely that printing/milling would be successful. Several small test models were printed to aid in this process.
When all the parts had been cut and printed, they were sanded lightly with 1000-1200 grit paper in some places (and the back of a brown paper bag in others) then glued together to create a whole. This whole forms a temporary positive, from which a mold will be taken using Polytech Polygel 40 and a fiberglass mother mold.

When this is complete, the mold will be taken and the final reproduction will be cast in Hydro-Stone gypsum cement, tinted to match the original ceramic.

Conclusion
3D scanning and printing are emerging technologies that provide enticing solutions to many of the obstacles inherent in creating mid- to large- size reproductions of artwork. While this is not the first 3D scanning project MACC has undertaken, it is the largest and most complex to date and relied on the skills of a professional scanning team as well as experienced mold-makers/printers/millers/sculptors.

The safety of the technique for the artwork itself was excellent and represents a minimally interventive approach, while the accessibility of the digital information will be an asset to the client. However, the finishing work required calls to question the ease-of-use of the process. It brings an element of both subjectivity and craftsman’s skill into a technique that was developed in part to avoid such things. Perhaps this is not entirely negative, and perhaps it should be no surprise that we find again and again, when working with objects of art, the human hand remains a necessity.

Acknowledgements
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Manually sharpened details are above the parting line.