Re-Printing Architectural Heritage

Exploring Current 3D Printing and Scanning Technologies

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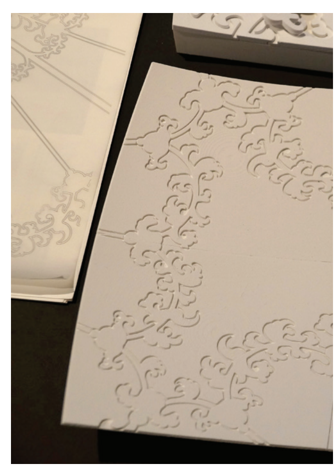
Abstract

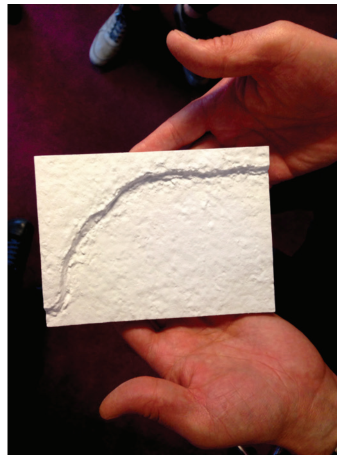
Additive Manufacturing (commonly known as 3D printing) technology has become a global phenomenon. In the domain of heritage, 3D printing is seen as a time and cost efficient method for restoring vulnerable architectural structures. The technology can also provide an opportunity to reproduce missing or destroyed cultural heritage, in the cases of conflicts or environmental threats. This project takes the Hippolytuskerk in the Dutch village of Middelstum, as a case study to explore the limits of the existing technology, and the challenges of 3D printing of cultural heritage. Architectural historians, modelling experts, and industrial scientists from the universities of Delft and Eindhoven have engaged with diverse aspects of 3D printing, to reproduce a selected part of the 15th century church. This experimental project has tested available technologies to reproduce a mural on a section of one of the church's vault with maximum possible fidelity to material, colors and local microstructures. The project shows challenges and opportunities of today's technology for 3D printing in heritage, varying from the incapability of the scanning technology to capture the existing cracks in the required resolution, to the high costs of speciality printing, and the limited possibilities for combining both printing techniques for such a complex structure.

Keywords

3D printing, 3D scanning, heritage, architecture

Connecting new technological developments in 3D scanning and 3D printing with cutting-edge research in the humanities and architectural design, the project aims at developing material reproductions of architectural heritage, to engage in research on the potential of 3D printing technology for heritage studies, and to explore the challenges and potential developments to the technology for both heritage professionals and affected communities. Careful historical study of available archival documents and earlier restorations helped us decide on a selection of the study object, a painting of an angel, riding a lamb, located in a vault near the choir. The painting depicts the last judgement, and is part of series of scenes made by Albrecht Dürer.




Throughout the process of scanning and printing the section, we encountered multiple challenges, varying from the incapability of the scanning technology to capture the existing cracks in the required resolution, to the high costs of speciality printing with particular materials, and the limited possibilities for combining both printing techniques for such a complex structure. Additional fundamental challenges have emerged from the decision-making process, with regards to issues of copying and replication, scale, presentation, and access to information.

Use of 3D scanning technology in the church's vault shows the multitude of challenges of such projects in the heritage field. Available 3D scans for the church, taken at ground level, lacked the level of detail we needed, requiring new scanning. As it was practically impossible to reach the required height with the scaffolds, the project members took color pictures and made the required scans with the laser scanner from as close as possible, with a resolution of around 0.5 mm and with the highest quality available.

Translating the 3D scans into usable data had its own difficulties. Combining photogrammetry with laser scanning, we developed 3D virtual models, and then selected a piece of about 15×20 cm for 3D printing trial. We selected the particular piece for scanning and printing, as it has little curvature (making the application easier for 3D printing of a colored surface), but included the crack (so that we could test the challenge of scanning and printing). Despite the high resolution, the depth of the structural crack did not appear clearly in the scan.

In the absence of printing technology that can apply a color to a non-flat surface, we decided to explore the opportunities of printing the painting on a thin film and applying it over a 3D printed structure with visible surface microstructures. In principle, the film print ought to take into account the deformation based on surface unevenness and curvature. While it is in principle possible to generate a computer model deformation (UV Mapping?), we decided to ignore this aspect for our pilot project.

Having separated the structural printing and that of the film, we opted to first experiment with materials for 3D structural (non-colored) 3D printing. The CAMlab of TU Delft produced a first gypsum test print without color, providing a good first impression of the surface structure. We found that the thin lines produced by the gypsum print technology were insufficient to render the texture of a wall surface. Additional test prints were produced by QUBICX, to experiment with different materials. This included: once coloured sandstone produced on the 3D systems ProJet660Pro, and one PA12 white (nylon) produced on a EOSint P770 SLS.

Both of these objects had the qualities necessary to serve as sub structure. To reduce the cost of printing material, we decided to hollow out the piece and to apply spider-like/honey-comb back structure. Using such a structure in the back would also hollow to use the process in architectural heritage to fill e.g. holes, or missing parts as an alternative to Styrofoam.

For the front structure, we discussed several options. Following on conversations with specialists and companies we had to accept that the inkjet option, which has been used in the reproduction of Rembrandt paintings was not possible for this project. Current technology can only print on flat surfaces and not the complex vault structure of the church, which includes cracks and a complex topography. Colored, structural 3D printing technology would give the object a "plastic" look, as the technology does not provide an inkjet quality yet. We therefore opted to print the final colors and textures on a thin flexible foil layer (50 microns) and fix it over the solid 3D structure, which in this case will have all the microstructures, and grains. Reducing the glossiness of the material as much as possible, so the final product can be similar to the church mural remains a challenge that we are trying to address through an additional matt layer.

To test the implications of this technology for architectural design, two educators have collaborated with students to complement the technological challenges. Given that contemporary printers can only produce tiles of a maximum size of YYY and YYY, Peter Koorstra (TU Delft) challenged students in the Form and Modelling design studio to understand the seam between these tiles as pattern. Juliette Bekkering and Barbara Kuit (TU Eindhoven) added yet another aspect to the research, through investigating the possibilities to reproduce the columns using concrete 3D printer.

The goal of the project, to be presented in March 2018 is a scaled 3D print of the entire scanned area with applied file. In the run-up to this event, a workshop entitled "Re-Printing Architectural Heritage" will bring together scholars from various fields to discuss the first outcomes of our research on the Hippolytus church and of a parallel project involving the Mauritshuis.