Re-printing architectural heritage

The Hippolytuskerk and Mauritshuis projects

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Figure 5.

RE-PRINTING ARCHITECTURAL HERITAGE: THE HIPPOLYTUSKERK AND MAURITSHUIS PROJECTS

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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 can be 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 or to express lost appearances, in the cases of conflicts or environmental threats. Researchers from TU Delft have led two experimental projects published respectively in Innovative Materials (volume 6 2018 and volume 1 2019). The projects show the challenges and possibilities of contemporary 3D printing technology for the 3D printing of heritage. The first one, a 4TU-project called 'Re-printing architectural heritage' focused on the Hippolytuskerk in the Dutch village of Middelstum. There, the group of researchers tested available technologies to reproduce a mural on a section of one of the church's vault with maximum possible fidelity to material, colours and local microstructures. Simultaneously, a second project was conducted at the Mauritshuis at The Hague. This to investigate and to discuss the potential of reprinting historical spaces as a copy.

The Hippolytuskerk project

The 4TU project Re-printing architectural heritage' took the Hippolytuskerk in the Dutch village of Middelstum as a case study to explore the limits of existing technology and to research the possibilities of 3D printing of cultural heritage. Architectural historians, model building experts and scientists from the universities of Delft and Eindhoven have been involved in various aspects of 3D printing, with the aim of reproducing different parts of the 15th-century church. For example, the available techniques were tested to reproduce a mural in one of the vaults of the church, as faithfully as possible to the original material, the colors and the microstructure.

By combining new technological developments in 3D scanning and 3D printing with research in the field of architectural design, the project team aimed to create material reproductions of architectural heritage. Eventually, the team selected a painting of an angel riding a lamb in a vault by the choir. The painting shows the Last Judgment and is part of a series of scenes by Albrecht Dürer. During the section's scanning and printing process, the researchers encountered several challenges, ranging from the impossibility

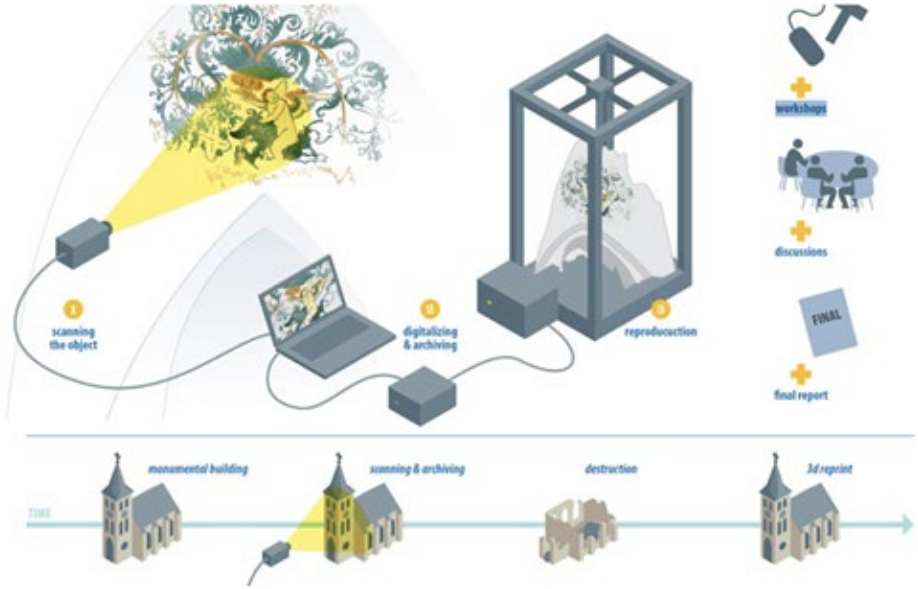

Figure 1. Infographic of the project re-printing architectural heritage (4TU Bouw)

of the scanning technology to capture the existing cracks in the required resolution, to the high cost of specialty printing with certain materials and the limited capabilities for combining printing techniques for such a complex structure.

Thin Film

In the absence of printing technology that can apply a color to a non-flat surface, it was 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 basically possible to generate a computer model deformation, the team decided to ignore this aspect for our pilot project.

Having separated the structural printing and that of the film, the researchers 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. The scientists 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.

Two methods

Two methods were tested: one with MultiJetPrinting, another with Selective Laser Sintering. In the first case, a colored sandstone model was produced on the 3D systems ProJet660Pro. The printer builds the model layer by layer and applies a thin layer of gypsum powder to the print table. The colored binder is printed on the plaster layer, following the shapes of the model for that specific layer. The binder is printed on the plaster using an inkjet printing technique. This system is also known as MultiJetPrinting (MJP). The color binder reacts with the gypsum powder that cures the material. After the print is complete, the unbound, unused plaster is removed for reuse. The printed object is then chemically post-processed resulting in vibrant colors and a strong model. The second model was printed with PA12 white (nylon) produced on an EOSint P770 SLS 3D printer. The PA12 powder is spread layer by layer on the print table in the same way as the first model. Only this time the material is bonded using laser beams. The result is a very accurate and strong model, also known as Selective Laser Sintering (SLS).Both of these objects had the qualities necessary to serve as sub structure. To reduce the cost of the printing material, the team decided to hollow out the piece and to apply spider-like/honey-comb back structure.

For the front structure, several options were discussed. The inkjet option appeared to be not suitable for this project. The team therefore decided 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 visible. Reducing the glossiness of the material as much as possible was one goal. To make the final product best resemble the church mural, we applied an additional matt layer. A 3D test print consisting of four panels was first exhibited at the Facade 2018 in Rotterdam in (January 2018). It has since been shown to the public at two other events.

Challenges

By combining 3D printing with a foil surface treatment, curators can experiment with reconstructions of paintings from different time periods, compared to the original. Such a comparison is especially effective when the print is viewed from a certain distance. However, a number of challenges remain. In this way, the foil retains a certain gloss that does not correspond to the original ceiling painting. In addition, the four panels that come together in the structure deformed during the drying process and the dividers remain visible despite the foil covering them. This problem is partly due to the thinness of the workpiece, which has been chosen in this case to save costs.

Proposals for a 3D print of a Middelstum church vault based on a new design could lead to a puzzle-like system that mimics the original decoration of the church. Such an

Figure 1a. On the left the 3D printed mural of the Hippolytuskerk van Middelstum; on the right the 3D printed section of the Golden Room of the Mauritshuis; both exhibited at TU Delft (Photos: TU Delft)

Figure 1b. The Mauritshuis 3D printed section

Figure 2.

Figure 3. Selection of the area to be printed

approach could be followed in future research and would take into account the specific material and technical qualities of 3D printing. Moreover, the technology used in this project is not the only one that has been tried out by the team. Research and a trial 3D print of part of the Golden Hall in the Mauritshuis have provided additional insights.

The Mauritshuis

The Mauritshuis is an aristocratic palace built in The Hague between 1633 and 1644, The Netherlands. Since 1822 it is a museum that houses the Royal Picture Gallery. The collection of Flemish and Dutch 17th century masterpieces is unique in the world. Due to its historical position for the Netherlands it was agreed to use this museum as a test case for the principle idea of reproducing a historical space by 3D-printing and to revive forms and colours that disappeared over the centuries.

Today, because of ageing of the materials, overpainting and renovations, the room looks very different from its original appearance. Margriet van Eikema Hommes studied, together with the conservators of the Mauritshuis, the original appearance of the Golden Room and has developed 2D reproductions this state. The 3D print helps translate the theoretical knowledge obtained and results from the 2D reproductions, in spatial 3d reconstructions.

The 3D print features a section of the room in its reconstructed original state, thus recreating a long lost spatial and esthetical entity. They provide the viewer new insights on the visual impact of this ensemble, its conceptual unity, its pictorial vocabulary and changes in perception history over time. In this way, the project connects technological and humanities cutting-edge research. First it was necessary to define a suitable section with sufficient texture and colour and finally a part of the so called Gouden Zaal (Golden Room) was selected.

Physical product

Next, various additive manufacturing technologies were investigated regarding to their suitability. In addition to the possibility of gypsum-based coloured components, plastic-based components were also investigated, which were coated with coloured foils. After examining a series of samples, a gypsum-based geometry was selected for this project. This promised the most accurate definition of colour and glossiness for the interpretation of the actual and historical space.

The next step was to physically create the selected section after digital processing. Due to the limitations of the dimension of the printers, it was necessary to divide the model into many components and to print these separately. In order to make the resulting cut lines appear as inconspicuously as possible in the model, cuts were made in such a way that they disappear into the geometric texture of the model.

Subsequently, the components were printed in their given geometry, texture and colouring and mounted on a supporting substructure. This substructure makes it possible to set up the resulting object as a stand-alone component. During the project, the process, the technologies and the first physical results were evaluated in different workshops. In addition, the physical result and process of the project were discussed and presented to a wider audience during the ‘research week’ of the Faculty of Architecture/TU Delft in November 2018.

Results

Related to the restricted budget and dimension of the printers, the limitations in quality and dimensions are obvious. It can be expected that with the development of more suitable technology and with an acceptance of the scientific and social potential, larger objects could be targeted to be reprinted.

Next to this, the quality of the printed results in texture, geometry and glossiness will increase and therefore allow a better likeliness of original and reprint. The general results of the project do deliver the expected process and physical results and by that reflect the expectation and deliver a first sketch concept of the process, technologies and physical results. Next to the internal evaluation of these results a public evaluation and discussion of the results and their implication for future projects has to take place in future follow-up projects.

Figure 4. Subsequently, the components were printed in their given geometry, texture and coloring and mounted on a supporting substructure. This substructure makes it possible to set up the resulting object as a stand-alone component

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The projects became posible through collaboration among numoerous participants:

Credits Middelstum project:

-Delft University of Technology: Prof. Dr.-Ing. Carola Hein;
Dr. Michela Turrin; Prof.dr.ir. Joris Dik ; John Hanna, Miktha Alkadri, Serdar Asut,
Prof.Dr.-Ing Ulrich Knaack; Peter Koorstra
- Eindhoven University of Technology: prof.ir. Juliette Bekkering, ir. Barbara Kuit
- Culrural Heritage Agency of the Netherlands: Albert Reinstra
- National Archives: Angela Dellebeke
- 3D idea printing – Dave Vanhove
- QUBICX: Dick Vlasblom
- Foundation for Old Groningen Churches: Jur Bekooy
- BLOMSMA PRINT&SIGN: Ron Teeuw -4Visualization: Valentin Vanhecke
- 3M Netherlands: Wim Oostveen

Credits Mauritshuis project

Delft University of Technology
Prof. Dr.-Ing. Ulrich Knaack (TU Delft)
Prof. Dr.-Ing. Carola Hein (TU Delft)
Prof. dr. Joris Dik (TU Delft)
Dr. Margriet van Eikema Hommes (TU Delft + Materials in Art and Archaeology & Cultural Heritage Agency of the Netherlands)
Partners:
Dr. Edwin Buijsen (Mauritshuis Museum)
Boy van den Hoorn (Mauritshuis Museum)
Dick Vlasblom (QUBICX)
Valentin Van Hecke (4Visualization)
Miktha Alkadri (TU Delft)

Illustrations

Fig. Subsequently, the components were printed in their given geometry, texture and coloring and mounted on a supporting substructure. This substructure makes it possible to set up the resulting object as a stand-alone component

Fig. On the left the 3D printed mural of the Hippolytuskerk van Middelstum; on the right the 3D printed section of the Golden Room of the Mauritshuis; both exhibited at TU Delft (Photos: TU Delft)