Photogrammetric 3D digitisation of models from an architectural collection

Andreas NOBACK, Technische Universität Darmstadt, Germany
Chris DÄHNE, Technische Universität Darmstadt, Germany
Roger WINKLER, Technische Universität Darmstadt, Germany
Stephan TITTEL, Technische Universität Darmstadt, Germany
Katja LEISKAU, Deutsches Architekturmuseum, Germany
Hasan KUTLU, TU Darmstadt & Fraunhofer Institute for Computer Graphics Research IGD, Germany
Reimar TAUSCH, TU Darmstadt & Fraunhofer Institute for Computer Graphics Research IGD, Germany
Martin SCHURIG, TU Darmstadt & Fraunhofer Institute for Computer Graphics Research IGD, Germany
Matevz DOMAJNKO, TU Darmstadt & Fraunhofer Institute for Computer Graphics Research IGD, Germany
Pedro SANTOS, TU Darmstadt & Fraunhofer Institute for Computer Graphics Research IGD, Germany

Keywords: *digitisation — architectural models — photogrammetry — research data management — specialised information service.*

CHNT Reference: Noback, A. Dähne, C., Winkler, R., Leiskau, K., Kutlu, H., Tittel, S., Tausch, R., Schurig, M., Domajnko, M. and Santos, P. (2021). 'Photogrammetric 3D digitisation of models from an architectural collection', in CHNT – ICOMOS Editorial board. *Proceedings of the 26th International Conference on Cultural Heritage and New Technologies*. Heidelberg: Propylaeum.

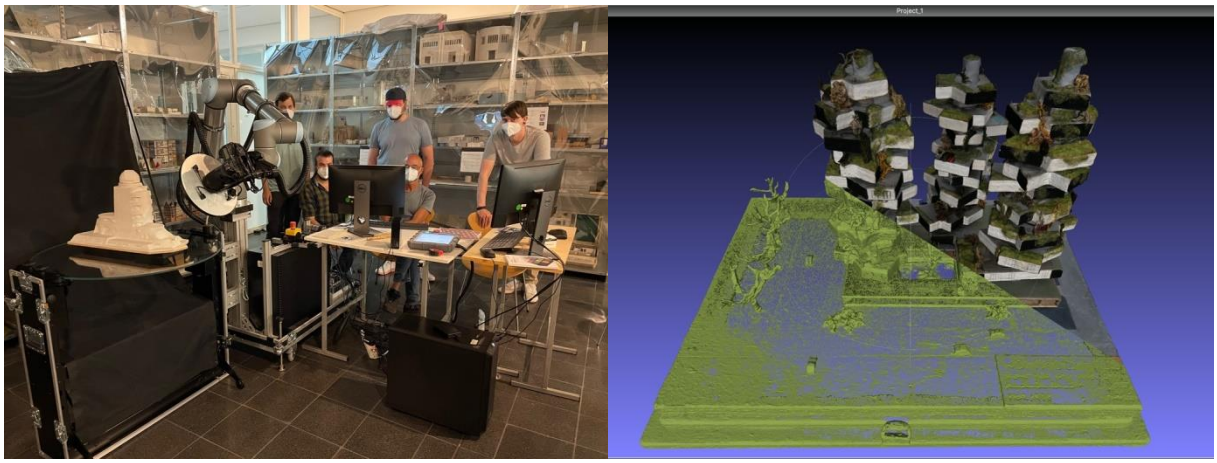

Figure 1: Automatic acquisition of an architectural model with the robotic setup consisting of a computer-controlled turntable and robotic arm with a lighting and camera system attached (left). "Wohnhochhaus" by Frei Otto as an exemplary digital model (right). The geometric structure of the complex building is preserved. Fine detail as the moss is coarsely represented. Acrylic glass that forms railings at the top levels vanished in the digital model. The resolution of the triangular mesh and the mapping is significantly lower than that of the measured data.

Introduction

For research in architectural history, 3D items as models and building details found in architectural collections between drawings, photos, correspondence and other 2D archival materials are important sources of information. Alongside the digital preservation and dissemination of digital born

data retro-digitalisation of museal collections and archives is a major task in providing more access to this kind of cultural heritage and foster the development of a semantic web of museal and historic information. While existing techniques and infrastructure provide adequate means for the digital acquisition, preservation, dissemination and display of data and metadata from 2D archival materials, architectural models are represented in the digital realm almost entirely by photographs, ignoring their most important characteristic. And while scholars in architectural history use data collections of 2D items on a daily basis, the utilisation and potential of 3D digitised architectural models has still to be explored.

Developing a digitisation service for architectural models

Against this background, the specialised information service (FID) BAUdigital[1] aims to provide a service for the retro-digitisation of architectural models complying with FAIR data principles (Wilkinson, et al., 2016). This includes the 3D acquisition and processing, the input and enrichment of metadata, a repository infrastructure – including digital preservation –, a web platform for search and display, and support for research communities developing around these digital items.

For the development of this service the collection of the Deutsches Architekturmuseum (DAM) – comprising almost 1600 models and an accompanying database – serve as a case study (Elser and Cachola Schmal, 2012). The digitalisation of not only a few, but a *significant portion* of the 3D items of a collection with respect to their semantic conjunction within this collection is key for research purposes.

For digitalisation photogrammetric acquisition is applied utilising the CultArm3D (Figure 1), a fully automatic and colour-faithful 3D-scanner developed by the Fraunhofer IGD (Santos, et al., 2020). The CultArm3D is capable of scanning arbitrary objects at reproducible high resolution by using its autonomous view planning feature that estimates camera focus, position, and orientation, making sure an optimal set of images for the photogrammetric reconstruction is captured. Therefore, it ensures sharp texturing on the whole visible surface of the scanned object.

Using the CultArm3D, the acquisition of exemplary models of the DAM is combined with a survey of the collection. The case study shall provide insight in two main aspects:

1. Foster the understanding of architectural models as research objects and collection items, informing the design of search and viewing infrastructure as well as metadata schemata and semantic data models.
2. Finding distinct challenges for digital acquisition of architectural models. Directed tests based on an overview of their common sizes, materials and typical spatial structure allows to develop suitable acquisition procedures and to better understand of the results as research objects.

[1] The FID BAUdigital is part of specialised information service program founded by the Deutsche Forschungsgemeinschaft and a collaboration of three large academic libraries (University Library Braunschweig, University and State Library Darmstadt, TIB - Leibniz Information Centre for Science and Technology) and the Fraunhofer Information Centre for Planning and Building.

Architectural models as artefacts, representations and collection items

One genuine characteristic of architectural models is that they are not only *artefacts* that relate to creators, design processes, techniques etc. but also *representations* of real – or fictional – architecture and therefore related to their locational, environmental, historic and social context etc. as well. Not in every case the creators of a model and their historic context are identical to those of the architecture they represent. As *collection items* they relate to other objects, e. g. within an architect's estate, a competition or a group of works. In the viewing infrastructure they have to be treated as 3D artifacts – turned, zoomed, composed, decomposed, compared etc. but also as buildings or urban environments with eye-levels, storeys and the possibility of walk-throughs. A metadata schema has to fit these tree views on architectural models as well as the scan result.

Size, spatial structure and materials of architectural models in the context of 3D acquisition

The current setup of the CultArm3D provides a scanning volume with a diameter of 0.45 m and a hight of 0.60 m. To scan 80% of the collection a diameter bigger than 1.30 m would be necessary (Figure 2). Often the outer limits are defined not by the model itself but by the ground plate of the original model or the base of a glass cover (Figure 1). The hight of the scanning volume is less often a limiting factor, but models of high-rise buildings can be challenging.

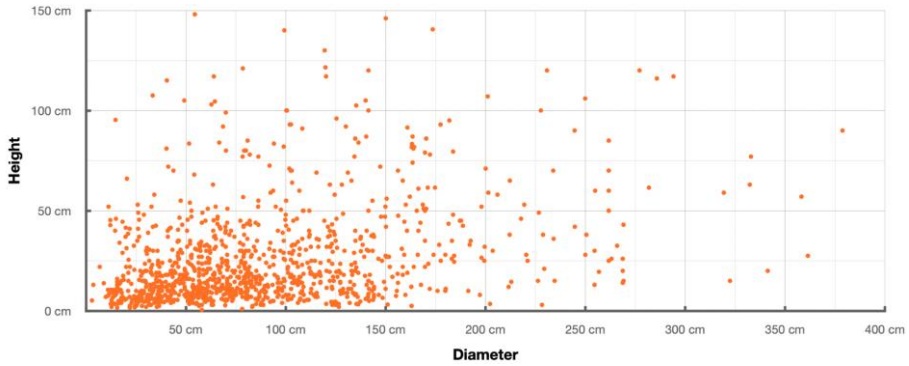

Figure 2: Diameter and hight distribution of the models in the collection of the Deutsches Architekturmuseum.

Architectural models often show complex spatial structures (Figure 1) with multiple building elements, courtyards, raised parts etc. Many models – especially of larger scales – allow insight into interior spaces resulting in deep cavities. Photogrammetry in general requires an object surface point to be seen and triangulated from multiple camera angles. That means, deep cavities can cause problems in photogrammetric reconstructions, because most camera angles are occluded. The Cult-Arm3D automatically resolves these occlusions in an iterative view planning approach.

Modern architecture often features light-weight constructions or includes trees, plants, and wires in its design. Thin and fine-scaled representations of these elements challenge the spatial reconstruction algorithms and are not easy to model with triangular meshes (Figure 1). While the results are accurate in regard to the overall form of these elements, they tend to feature somewhat coarse detail. To capture even more details in sufficient resolution, a microscopic camera setup would be required. However, this would limit the measurement volume and thus significantly increase in scanning

duration. More study is required to solve this trade-off problem between the measurement volume and the scanning duration.

Architectural models are comprised of a wide range of materials, typically in mixed arrangements. Some materials cause problems in the acquisition process, namely highly specular and glossy surfaces. Featureless surfaces provide challenges as well, however tests with white plaster models gone surprisingly well. To suppress specular reflections, the lighting and camera system of the setup is equipped with crossing polarisation filters. As a side-effect this causes transparent acryl glass to vanish (Figure 1). The same is true for the fine relief of wood grain that is visible through small shadows that are suppressed by the lighting system.

3D acquisition is only the first step in the pipeline of a retro-digitisation service. A microservice driven digital workbench allows to add metadata, generate web-enabled 3D representations and to upload to the repository and digital preservation infrastructure. It is developed in the context of handling similar 3D data in the FID BAUdigital and in cooperation with users and the growing family of similar research data initiatives.

Preliminary conclusions and outlook

The digitalisation of a significant portion of models from an architecture collection is a challenging task. The heterogeneity of the objects requires further systematic study and probably a range of distinct adaptations of the acquisition procedures. Naturally, digital representations are not 1:1 copies of the originals. Additionaly, photographs of the models can capture characteristic that are not covered by the 3D scans. It is part of the process of understanding 3D acquisition of architectural models as a method to study which of their aspects it can represent in the digital realm.

Its strengths and limitations are only meaningful in the context of the *application* of a method. A new method has to provide additional means for research. 3D digitalisation offers a more ample access to this cultural heritage. 3D models offer unique possibilities for VR and AR applications. For example, it is possible to virtually combine the different models of a competition with the environment model to understand the juror’s decision or you can view a model at its designated location from street level. The further understanding of 3D representations of architectural models as research objects and their useful application is instructive for the development of enhanced metadata schemata and a task for the historic architecture community as a whole.

Funding:

The FID BAUdigital is supported by the Deutsche Forschungsgemeinschaft (DFG #432774435).

Conflict of Interests Disclosure

The authors declare no conflict of interests.

Author Contributions

Investigation: Stephan Tittel, Reimar Tausch, Martin Schurig, Matevz Domajnko, Pedro Santos

writing – original draft: Andreas Noback

writing – review & editing: Chris Dähne, Roger Winkler, Katja Leiskau, Hasan Kutlu

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