Piotr Kuroczyński, Dietmar Popp, Oliver Hauck, Martin Scholz, Carsten Neumann, Torsten Veit, Jan Lutteroth, Arthur Sarnitz, Daniel Dworak, Maria Pietruszka

VII. Digitale 3D-Rekonstruktionen in virtuellen Forschungsumgebungen

→ Datenmodellierung, Digitale 3D-Rekonstruktion, Digitale Forschungswerkzeuge, Dokumentation, Virtuelle Forschungsumgebungen, Visualisierung

Das Projekt »Virtuelle Rekonstruktionen in transnationalen Forschungsumgebungen – Das Portal: Schlösser und Parkanlagen im ehemaligen Ostpreußen« untersucht den gesamten Prozess der digitalen 3D-Rekonstruktion verloren gegangener Architektur. Die Ergebnisse basieren auf der Rekonstruktion zweier zerstörter Barockschlösser, Schlodien (Gładysze / Polen) und Friedrichstein (Каменка / Russland), und bringen neue Erkenntnisse für die Quellenerschließung, Dokumentation, semantische Modellierung und webbasierte Visualisierung von 3D-Datensätzen. Der Schwerpunkt liegt dabei auf der Entwicklung eines mensch- und maschinenlesbaren Datenmodells (Applikationsontologie), einer kollaborativen virtuellen Forschungsumgebung und einem Prototyp des »Virtuellen Museums«.

Das von der Leibniz-Gemeinschaft zwischen 2013 und 2016 geförderte Forschungsprojekt (**www.patrimonium.net**) verfolgte das Ziel die digitale 3D-Rekonstruktion als eine wissenschaftliche Forschungsmethode und ihre im Ergebnis vorliegenden digitalen 3D-Datensätze als nachhaltige Informationsträger zu untersuchen. 01

Angesicht der vielfältigen ungelösten Fragestellungen nach der Nachhaltigkeit, der Zugänglichkeit und Nachvollziehbarkeit der Projektergebnisse aus einer quellenbasierten digitalen 3D-Rekonstruktion vereinte das Projekt ein breit aufgesetztes interdisziplinäres Team aus Architekten, Kunsthistorikern, Historikern, Informatikern und Computergraphikern.

Von zentraler Bedeutung für das Projekt war die konzeptionelle Modellierung der projektspezifischen Sachverhalte. Die Analyse der Sachzusammenhänge und Prozesse einer digitalen 3D-Rekonstruktion sowie die Festlegung der Entitäten und Relationen in einem Datenmodell, stellt die Grundlage für die spätere digitale Erschließung der Forschungsdaten, die Nachhaltigkeit und Nachvollziehbarkeit der Ergebnisse dar. 02

Im Laufe des Projekts wurde die erste Applikationsontologie für die mensch- und maschinenlesbare Wissensrepräsentation einer digitalen 3D-Rekonstruktion entwickelt und somit eine Pionierarbeit auf dem Gebiet der Wissensorganisation und -repräsentation geleistet. 03 Die **chml-ontology** ist CIDOC CRM (ISO 21127:2006) referenziert 04 und innerhalb einer den Anforderungen entsprechend angepassten **virtuellen Forschungsumgebung** (VFU) implementiert. Die VFU fußt auf der web-basierten kollaborativen **wissenschaftlichen Kommunikationsinfrastruktur** (WissKi) 05, die zum einen alle Prozesse digitaler 3D-Rekonstruktion, wie die Erfassung, Erschließung und Interpretation der Quellen sowie anschließende hypothetische Rekonstruktion und den Diskurs rund um die 3D-Modelle, fach- und grenzüberschreitend ermöglicht. Zum anderen werden alle erfassten Informationen als strukturierte Forschungsdaten in einem RDF-Triple-Store (semantische Graph-Datenbank) gespeichert. Die Anbindung an weitere relevante Linked-Open-Data-Ressourcen, wie kontrollierte Vokabulare und Normdaten, stellen die digitalen Forschungsdaten in einem größeren Kontext und reichern diese mit einer höheren Bedeutung an.

Das Projekt untersuchte neben der Datenstrukturierung und Modellierung die web-basierte Visualisierung der 3D-Modelle (basierend auf der WebGL-Technologie). Hierzu wurde ein 3D-Annotationswerkzeug vorgestellt, welches einen direkten Diskurs an den 3D-Datensätzen erlaubt. Die interaktiven Annotationen im 3D-Viewer wurden mit den semantischen Instanzen der Datenbank verknüpft.

■01
Projektseite unter https://www.herder-institut.de/go/Q-338d9c2.

■02
Piotr Kuroczyński, Oliver Hauck, Daniel Dworak, 3D models on triple paths – New pathways for documenting and visualising virtual reconstructions, in: Sander Münster, Mieke Pfarr-Harfst, Piotr Kuroczyński, Marinos Ioannides (Hg.), 3D Research Challenges in Cultural Heritage II – How to manage data and knowledge related to interpretative digital 3D reconstructions of Cultural Heritage, Heidelberg, Cham 2016, S. 149–172.

■03
Vergleiche hierzu die Einführung zum 4. Kapitel Wissensorganisation und -repräsentation (Kuroczyński → 330).

■04
Die CHML-Applikationsontologie (Version 1.1) liegt im RDF-Format auf Github vor, https://github.com/chml-3d/chml-ontology.

■05
http://wiss-ki.eu/.

Darüber hinaus beschäftigte sich das Projekt mit dem niederschwelligen Zugang zu den Ergebnissen einer digitalen 3D-Rekonstruktion. Der Prototyp des web-basierten **Virtuellen Museums** ermöglicht die Zusammenstellung einzelner 3D-Modelle zu einer Gesamtszene mittels der WebGL-Technologie, so dass interaktive Spaziergänge durch verschiedene Zeitschnitte der Barockschlösser ermöglicht werden konnten. 06 Das **Virtuelle Museum** erlaubt dem Besucher einen explorativen Zugang zur 3D-Visualisierung und ihr zugrundeliegenden Ausgangsinformation. Die direkte Verknüpfung der 3D-Modelle und ihrer visuellen Darstellung mit den strukturierten Forschungsdaten des gesamten Rekonstruktionsprozesses gewährleistet die Nachvollziehbarkeit und Nachhaltigkeit der Forschungsergebnisse.

Zusammenfassend lässt sich sagen, dass viele eingangs vorgestellten Fragestellungen im Laufe des Projektes erstmals beantwortet werden konnten, auch wenn die Lösungen im Einzelnen aufgrund der begrenzten Zeit- und Personalressourcen nicht zu einem markttauglichen Produkt für die breite objekt-orientierte Forschung umgesetzte werden konnte. So lässt sich sagen, dass die Benutzerfreundlichkeit der VFU hinsichtlich der grafischen Schnittstelle und Nutzererfahrung, neben der Datenmodellierung und 3D-Visualisierung, von zentraler Bedeutung ist.

Die Abschlusstagung zum Projekt wurde veranstaltet vom **Herder-Institut für historische Ostmitteleuropaforschung** und dem **Institut für Kunst- und Bildgeschichte der Humboldt-Universität zu Berlin**, in Kooperation mit den **Berliner Gesprächen zur Digitalen Kunstgeschichte** und der **Arbeitsgruppe Digitale 3D-Rekonstruktion** beim Verband der Digital Humanities im deutschsprachigen Raum e. V., an der Humboldt-Universität zu Berlin am 19. und 20. Juni 2017. Die offizielle Internetseite zur Abschlusstagung ist unter **http://www.3d-digital-heritage.info/** zu finden.

Im Folgenden werden die **Abstracts** aus der Abschlusstagung vorgestellt. Die Screenshots von den Video-Mitschnitten verweisen über einen Web-Link zur Dokumentation auf der Seite **http://www.kunstgeschichte.hu-berlin.de/2017/09/3dheritage-bgdk6-dokumentation/.**

■ **06**
Daniel Dworak, Piotr Kuroczyński: Virtual Reconstruction 3.0, New Approach of Web-based Visualisation and Documentation of Lost Cultural Heritage, in: Marinos Ioannides et al. (Hg.), Digital Heritage. Progress in Cultural Heritage: Documentation, Preservation, and Protection. EuroMed 2016. Lecture Notes in Computer Science, vol 10058. Springer, Cham 2016, S. 292–306.

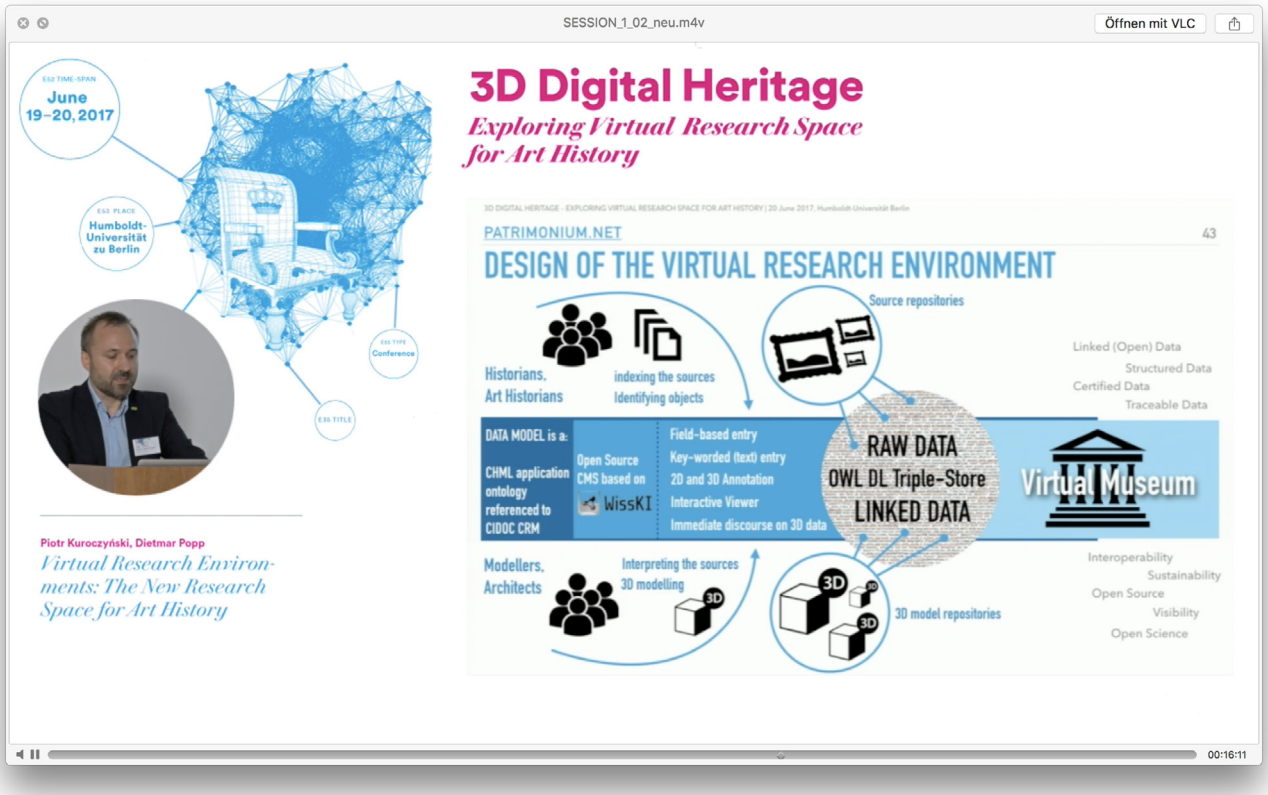
VII.1 Virtual Research Environments: The New Research Space for Art History

The amount of sourced-based digital 3D reconstructions and computer-based visualisations of cultural heritage have been increasing for almost three decades. Virtual reconstruction and 3D visualisation have opened up a new **glittering** research space for object-oriented disciplines such as archaeology, art history and architecture. Nevertheless those academics concerned with this emerging technology soon realized documentation standards were missing from many 3D projects, leading to the loss of important information or aggregated findings, along with the lost opportunity to consolidate the source knowledge and paradata that led to the creation of the digital 3D representation.

Guidelines on computer-based visualisation and 3D documentation (e. g. metadata) have been introduced in the last decade. The recent academic commitment to the design and application of Virtual Research Environments (VRE) for 3D research projects is promising. These VREs are under construction: they require further research and the establishment of a sustainable digital research infrastructure.

The three-year project **Virtual reconstructions in transnational research environments – the Web portal ›Palaces and Parks in former East Prussia‹** addresses key issues such as the lack of documentation standards, sustainability and accessibility of digital research data and the web-based scientific visualisation of the 3D content. The focus is on introducing sustainable digital 3D reconstruction, which is approved by scholars, complaint with recognised documentation standards, and follows Linked Data requirements.

The presentation introduces the methodological fundamentals, potential and challenges of digital 3D reconstruction, arguing that a scientific methodology and collaborative web-based research environment are crucial features for this kind of project. The groundwork for a human- and machine-readable **language of objects** and the implementation of these semantic patterns for spatial research purposes on destroyed and / or unrealised cultural heritage will also be discussed. Illustrated by practical examples and experience derived from the above research project, the presentation explains the requirements of the Semantic Web (Linked Data), the role of controlled vocabularies, the architecture of the VRE and the impact of a customised integration of interactive 3D models within WebGL technology. The aim is to showcase the state of the art at this stage in the development of a digital research infrastructure.



☐ 01
Videoschnitt vom Vortrag von Piotr Kuroczyński und Dietmar Popp (Humboldt-Universität Berlin, 2016), **http://www.3d-digital-heritage.info/#ref_1073**

VII.2 Methodology, Data Models and Implementation in the ViReBa Virtual Research Environment

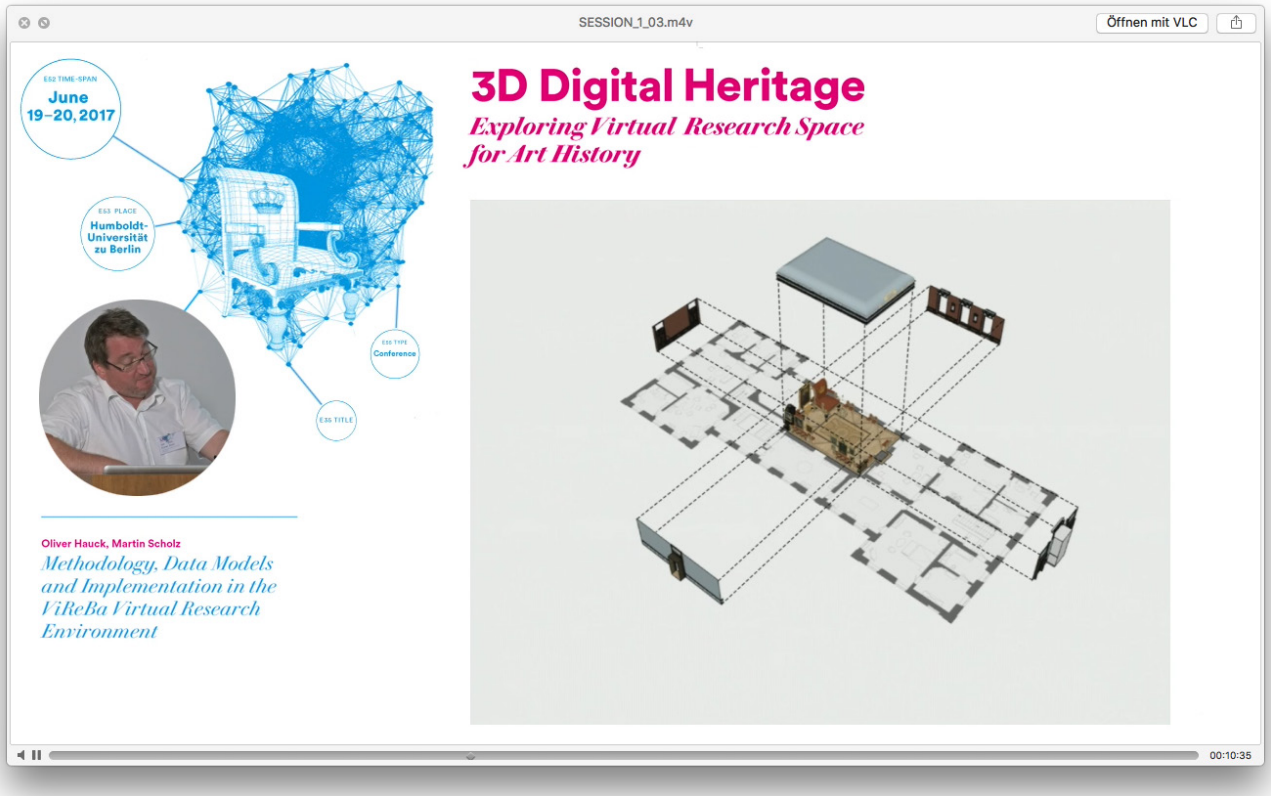
This talk takes a look behind the scenes of the Virtual Research Environment (VRE) patrimonium.net, which deals with the virtual 3D reconstruction of destroyed ancient baroque manor houses, buildings and gardens. It served as the working platform for the project **Digital 3D Reconstruction in Virtual Research Environments** that ran from 2013–2016.

A central research aspect was the development and application of documentation techniques for 3D models and the impact of this documentation on the 3D modelling process. Semantic modelling is not new to the field of architecture: Building Information Modelling (BIM) is a planning method commonly used by architects. The talk will show how BIM has been applied using common 3D modelling software in 3D reconstruction, which is the basic recommendation for using the models in the VRE, and in a virtual museum, with parts of the 3D model representing all the information behind them in the database.

The reconstruction model is enriched by metadata describing its complex creation history, with a focus on sources used for its creation, such as visual and audio sources or measurements, with the aim of making every decision taken by the reconstructing staff transparent and revisable. This information is combined and represented as a flexible knowledge graph.

At its core, the data model consists of an alignment of the Cultural Heritage Markup Language with the CIDOC CRM in the form of an OWL domain ontology, taking advantage of Linked Open Data and the Semantic Web.

Handling the complexity of the CIDOC CRM and the domain ontology on the one hand, and the graph like data model on the other, however, is not an easy task for researchers that are not especially trained. Thus, patrimonium.net makes use of the WissKI system (Wissenschaftliche Kommunikations-Infrastruktur), which mediates between the data model's peculiarities and the researchers' digital abilities. By defining ontology paths, complex information in the knowledge graph can be translated to well-known tabular metadata visualisations. The data graph is further enriched by automatic annotation extraction from free text. Finally, patrimonium.net features a 3D model annotation tool, where the annotation data is stored as triples according to the ontology.



☐ 02
Videoschnitt vom Vortrag
von Oliver Hauck und Martin Scholz
(Humboldt-Universität Berlin, 2016),
http://www.3d-digital-heritage.info/#ref_1074

VII.3 »Königsschlösser« in the Light of Digital Art History

The East Prussian manor houses and estates and their owners shaped the region in many ways. On the one hand, they were closely linked to the royal court as **royal palaces**; on the other, they were not only an architectural expression of the rise of their builders, but also an administrative and representative centre of extensive property complexes.

An essential basis for our work was the figurative, textual and material traditions from the archives and collections of the Dohna and Dönhoff families. In addition, the architectural history of the manor houses, their individual furnishings and art historical classification all required further research. The reconstruction and 3D modelling of our scientific work was also researched. At the end of the project, today's estates and the building histories were documented in photographs, and we continued to modify the 3D models.

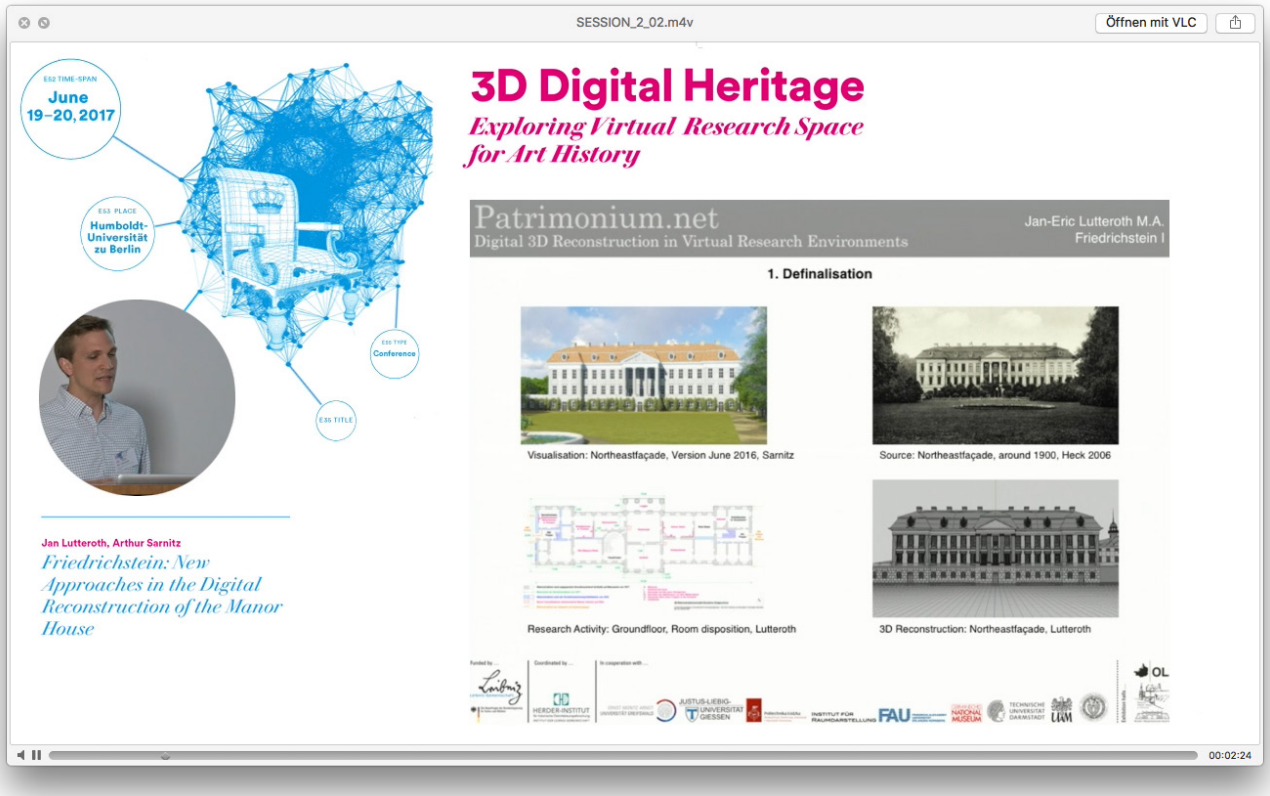
Two exemplary research results are presented here. Firstly, we share some reflections on the history of the building at Schlodien as part of its architectural history, based on a survey of the manor house ruins carried out in April 2016. The focus was on the baroque core construction, without the additions from the 19th century. Secondly, we discuss comparative examples concerning one of the most important pieces in the palace. The painting of Frederick I has been lost since 1945, but the importance of this work of art is evident from historical photographs. Creating a 3D reconstruction of such an opulent work of art raised some complications that had to be overcome. Thirdly, we consider the advantages and disadvantages of the digital tools used. On the one hand, this concerns the practicality and user-friendliness of the software solutions for research, and on the other, the complications resulting from interdisciplinarity and influencing parts of the daily workflow. Both are necessary sources of information to determine the value of this project and the developed tools for the future of art historical research.

☐ 03
Videoschnitt vom Vortrag
von Carsten Neumann und Torsten Veit
(Humboldt-Universität Berlin, 2016),
http://www.3d-digital-heritage.info/#ref_1075

VII.4 Friedrichstein: New Approaches in the Digital Reconstruction of the Manor House

This presentation exemplifies the workflow structure used for the digital 3D reconstruction of the Friedrichstein manor. It outlines the advantages of the underlying semantic database for collaborative division of tasks and modelling control within an international research team. Documenting a comprehensive workflow is an essential part of creating a scientific digital reconstruction model, as it allows for important data analysis and use after the project.
The Virtual Research Environment (VRE) introduced by the project guides the modeller through three key steps to create paradata (as demanded by the London Charter) that form the basis for conscientious after-use of the 3D model. Firstly, the VRE allows the researcher to integrate, compare and comment on all sources used in the modelling process. During this viewing step, a logical building structure needs to be developed in order to precisely reference the sources relating to parts of the building. This second step of dividing the building into its essential parts also determines the level of detail that will evenly be used in the model. Finally, the VRE allows the modeller to verbally and visually describe modelling decisions in combination with the previously generated sources and building structure, hence allowing any follow-up researcher to easily retrace the information leading to the digital reconstruction model. This web-based research environment has the benefits of **de-finalising** any visualisation rendered from the 3D model, displaying modelling decisions and their critique within a collaborative work structure. Perhaps more importantly, it enables further evaluation and interpretation of the generated 3D model and its paradata.

Arthur Sarnitz will report on SketchUp 3D software for analysing incoming data from VRE as 3D models, vector and raster drawings and maps.
The presented workflow can work with many file formats, natively or by using plugins and is precise enough for historical 3D reconstruction requirements based on various sources. It is well suited to 3D modelling and photorealistic texturing for later reuse in external software for architectural visualisation, such as Lumion3D. The presentation will focus on Lumion3D to combine all the available models in one huge scene and set up real-time shaders for sky, terrain, grass, foliage, real location sun study and animation.



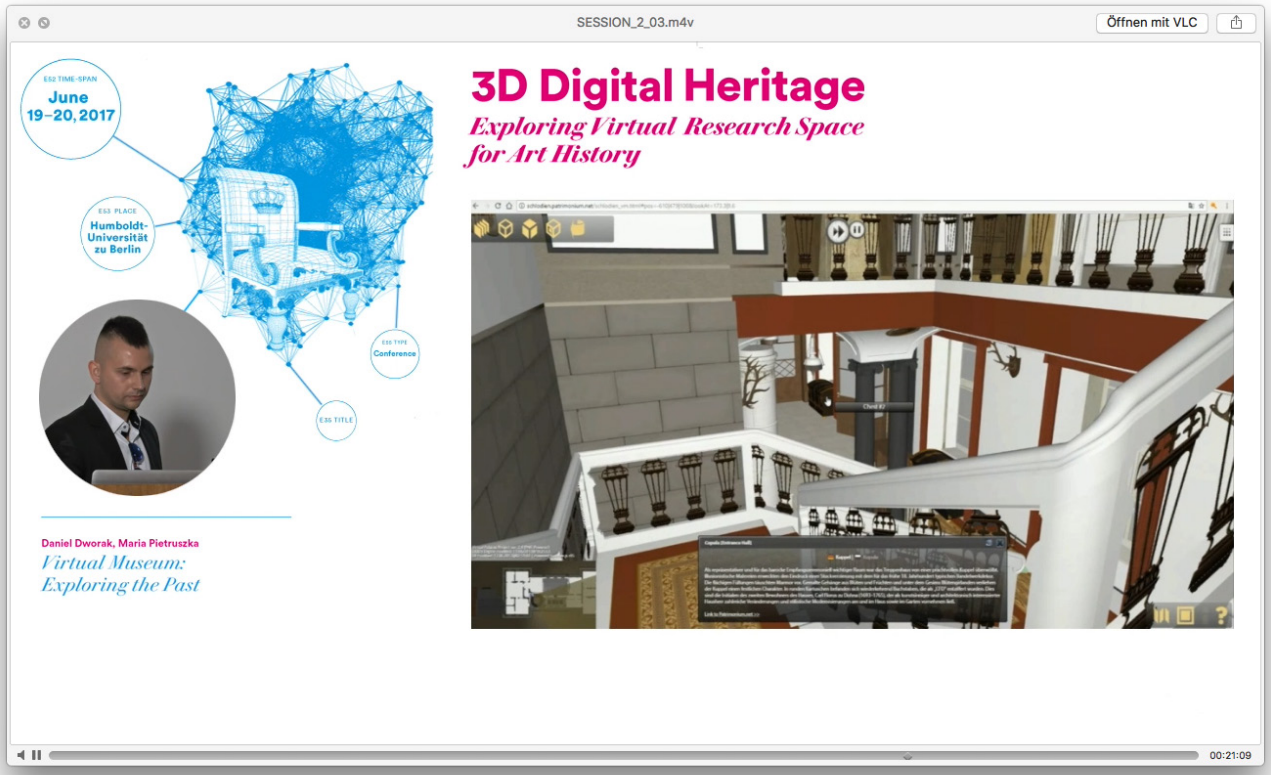
☐ 04
Videoschnitt vom Vortrag
von Jan Lutteroth und Arthur Sarnitz
(Humboldt-Universität Berlin, 2016)
http://www.3d-digital-heritage.info/#ref_1078

VII.5 Virtual Museum: Exploring the Past

In 2013, Lodz University of Technology prepared basic requirements and assumptions for virtual reconstructions, because these are burdened with many restrictions and unsolved problems. WebGL technology was chosen from a range of options (such as Stage 3D, Away 3D, and X3D), as it is the most promising cross-platform, plugin-free, and sufficiently stable environment in development which can be used to create a layer between the user and virtual world (Model-View-Controller). Steps have been taken to solve or minimise existing problems with 3D Web technologies. There is no single, strictly performed and consistent workflow for visualising 3D content and proposed file formats. During Daniel Dworak's 6-month supervision in Frankfurt, it was confirmed that there are many different modelling techniques and software options that produce inaccurate data during the exporting / importing process. We found that many participants have different skills and use a variety of tools (such as software, file formats, or textures). Based on this experience, we composed a short document explaining how 3D models should be created, which is ready to be shared online.

Annotations of sources and 3D models were another important part of our task. We developed an interactive, platform-independent and Internet-accessible environment for preparing annotations, connections between them and actions, that is used by specialists in different fields (e. g. historians and modellers) to exchange their suggestions, doubts or sources of concern.

The Virtual Museum appeared to be **the collection** of many proposed, developed and examined techniques for 3D Web. Performance, interactivity, and sufficiently realistic and authentic experience were treated as key elements throughout the workflow. As a result of the author's idea of coding and decoding 3dPNG files even up to ten times, 3D data can be downloaded more quickly. The process of decoding this data has also been improved by using general processing on graphics processing units. Techniques from computer games like portaling, hotspots, model splitting and many more proved necessary. We also considered the user's experience, proposing a user-friendly interface with carefully selected elements and mechanisms for exploring the 3D space.



☐ 05
Videoschnitt vom Vortrag
von Daniel Dworak und Maria Pietruszka
(Humboldt-Universität Berlin, 2016),
http://www.3d-digital-heritage.info/#ref_1082