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Documentation and Evaluation of Virtual Reconstructions

Marc Grellert[1], Markus Wacker[2], Jonas Bruschke[2], Wolfgang Stille[3], Daniel Beck[3]

[1]*Technische Universität Darmstadt, FG Digitales Gestalten, El-Lissitzky-Straße 1, 60487 Darmstadt, grellert@dg.tu-darmstadt.de*
[2]*HTW Dresden, Fakultät Informatik/Mathematik, Friedrich-List-Platz 1, 01069 Dresden, {markus.wacker, jonas.bruschke}@htw-dresden.de*
[3]*Technische Universität Darmstadt, hessian.ai, Mornewegstraße 30, 64293 Darmstadt, {wolfgang.stille, daniel.beck}@hessian.ai*

***Abstract* – Virtual reconstructions have become widely established as communication and research tools in the context of architectural and urban studies. To make these reconstruction solutions more transparent and to allow for their assessment and recognition, it is of vital importance to document and evaluate the reconstruction processes. However, currently, such documentation, which would facilitate the scholarly analysis of the results, is only compiled in isolated cases. The DFG-funded project IDOVIR (Infrastructure for Documentation of Virtual Reconstructions) provides the community with a freely accessible, free of charge, and user-friendly platform (https://idovir.com) for documenting sources, reconstructions and decisions quickly and economically. From variants and different evaluation schemes for reconstructions and sources, the versatile tool allows the user to indicate the plausibility and informational value of the sources and the reconstructions based on them.**

I. INTRODUCTION

In the context of architectural and urban research, virtual reconstructions have become widely established as communication and research tools [1]. They often visualise architecture that no longer exists, but also historical construction projects that were never realised, earlier states of buildings or even entire cities. During a reconstruction process, a wide range of sources, some of which may well be contradictory or ambiguous, can play a role and be interpreted and evaluated in very different ways. For this reason, there has been a longstanding and well-underpinned call for reconstruction results to be accompanied by a documentation of the sources and, above all, a documentation of the decision-making processes that support them, in particular the London and Sevilla Charter [2, 3]. Although there is now a consensus that research results should be available in a transparent, permanent and openly accessible form, this still tends to be the exception rather than the rule, and there is a real risk of losing the knowledge embedded in reconstructions [1, 4].

Several reasons can be cited for this unfortunate state of affairs: To date, documentation is generally neither explicitly demanded by the funding bodies, nor are additional funds made available for it. Thus, it is mostly left to the individuals and institutions who create a reconstruction to finance a documentation with their own means. Moreover, not only is there no universal agreement on the standards, structure, and content of such documentations, there is also a shortage of established tools to support this work in such a way that users will recognise a clear added value in its reusability and ideally perceive it as facilitating the reconstruction process through intelligent software support instead of merely seeing it as extra work or a cumbersome bureaucratic formality.

At the latest since the EPOCH Research Agenda [7] 2004-2008, the subject of documenting 3D reconstructions has come into focus. One result of that four-year research project was the aforementioned London Charter, which remains decisive for subsequent theoretical considerations and their practical implementation. For some years now, there have been tentative attempts in the professional community to meet the challenge posed by the lack of documentation with concrete proposals for solutions. Demetrescu & Fanini [8] and Wacker & Bruschke [4] provide a good summary of these. A first draft for a systematic documentation tool was developed by Pletinckx [9] in the form of a web-based tool built on wiki technology. The aim was to systematically document sources, their interpretation, the formulation of hypothesis and the resulting visualisations. To ensure data exchange, metadata standards came under increasing consideration.

One standard that received particular attention in the field of 3D digital reconstructions is the CIDOC Conceptual Reference Model (CIDOC CRM) [10], an ontology in the field of cultural heritage that was originally designed for use in museums. Despite various extensions, for example for digital objects [11], there remains a degree of ambivalence in the way certain kinds of information are linked. Moreover, the input and retrieval of data can be far from intuitive. Nevertheless, there are projects that try to integrate the CIDOC CRM in 3D reconstructions. A web-based prototype, in which both the sources and their provenance and the reasoning behind the reconstruction decisions were linked to a 3D model, was developed by Guillem, Zarnic & Bruseker [12]. WissKI[1] is a system that uses Semantic Web technologies to build on CIDOC CRM and also allows for the integration of various vocabularies and thesauri. It is primarily intended for institutions and the documentation of collections and archival holdings.

Also under discussion as a basis for the documentation of 3D reconstruction is the use of Building Information Modelling (BIM), familiar from the construction industry [13, 14]. MonArch [15], a documentation system that is geared towards the field of building research, also seeks to implement and advance the integration of BIM. However, this system focuses on recording existing buildings.

Coming from archaeology, Demetrescu [16] takes a completely different approach. Here, virtual reconstruction is seen as an extension of the findings during excavations. To also allow for the documentation of virtual elements and sources, the methods and tools typically used in archaeology, especially stratigraphy and the Harris matrix, are expanded accordingly. A prototype of an interactive tool for the visualisation and exploration of data in connection with 3D models has already been developed [8].

Many practitioners addressed specific aspects of documentation. Of particular interest here is the degree of uncertainty associated with fragmentary or otherwise incomplete source material that can be interpreted in a wide range of ways. Various metrics have been developed, among them that of the Level of Hypothesis [17] or a classification that takes account of a source's information content, ambiguity and need for interpretation [18]. The question of visualising the different levels of uncertainty and reliability directly on the model has also been discussed in several publications [19, 20].

To meet the demand for the documentation of research results in a practical form, two prototype web applications (ScieDoc and DokuVis) were developed at the TU Darmstadt, Department of Digital Design, and at the HTW Dresden, Faculty of Computer Science/Mathematics, respectively. They later merged in the development of the online tool IDOVIR funded by the DFG (German Research Foundation). The latter builds on the approaches of ScieDoc and DokusVis and combines the advantages of the two precursor systems.

IDOVIR documents the research results in such a way that the decisions as to why a reconstruction was drawn up in the way it was, what sources it is based on, what other variants were considered, but also which conceivable variants were rejected and for what reason (traceable, transparent documentation of negative results), are documented and made accessible via the internet. At the same time, IDOVIR supports communication among the parties involved in the development of a reconstruction and is intended to help structure the process of reconstruction in a meaningful way.

[1] https://wiss-ki.eu/

The fundamental idea of IDOVIR is based on the Reconstruction Argumentation Method (RAM) developed at the TU Darmstadt and already used in ScieDoc as early as 2017 [21, 22]. At the heart of the RAM approach is the subdivision of a reconstructed building into different areas (see section ii.). Each of these areas is represented by 1) renderings of the *reconstruction*, 2) images of the *sources* used, and 3) a *textual argument* explaining how the sources have given rise to the reconstruction. For each area it is possible to represent several variants within this triad of reconstruction – sources – argumentation (cf. Fig. 1). Whereas ScieDoc relied on two-dimensional renderings to represent the reconstruction, IDOVIR picks up on the 3D approach of DokuVis [23] and offers both 2D and 3D representation. The RAM approach is already being adopted in other projects to establish methodological standards for the documentation of reconstructions [24].

Essential for the assessment and evaluation of the reconstructions is a classification of the sources and how they were used in the project. A customisable scale can be used to evaluate the reconstructions in terms of geometry, surface structure and colouring. This allows for the assessment and communication of the available data, their quality and reliability. An overview of the workflow is given in Fig. 2.

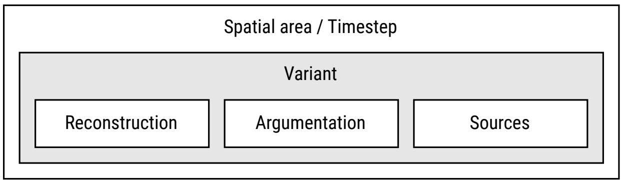

Fig. 1. Core structure unit of a spatial area or timestep that contains at least one variant and the RAM triplet.

II. SPATIO-TEMPORAL STRUCTURING

Structurally, IDOVIR allows for the subdivision of the buildings or urban complexes that are to be reconstructed into different spatial areas and time periods. Users are free to choose their own designations, subdivisions and hierarchies in a tree structure (cf. Fig. 3). IDOVIR makes it very easy to configure, expand and change this structure as required. In the next step, using RAM, reconstructions, the underlying sources and the argumentation that led to the reconstruction can be entered into the tree structure (Fig. 4). They form the core of the IDOVIR system and constitute the semantic knowledge of the origin of the data (paradata). The sources and reconstructions are kept in a separate col-

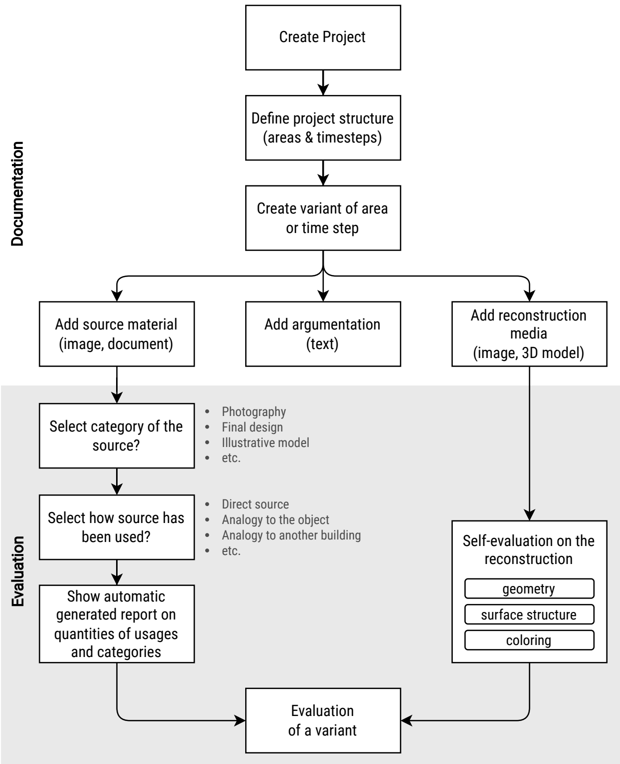

Fig. 2. Workflow of documentation and evaluation in IDOVIR.

lection and can easily be accessed, edited and referenced from every substructure of the project. The category of variants is subordinate to the structural levels of areas/time periods.

III. VARIANTS

The option of creating variants within the hierarchical structure is rooted in the realisation that architectural reconstructions rarely result in a single, unambiguous version of a building or complex, and that it is important to record the underlying discourse in its entirety. This means that further plausible variants, as well as those that may have been rejected, should be recorded and documented. If new findings change the factors that had previously led to the rejection of a variant, it is possible to refer back to those earlier discussions.

While it is easy to represent variants in reconstructions by means of two-dimensional illustrations based on renderings of the respective model variants, the representation of variants by means of 3D models is more complex and may entail uploading many similar models. Here it might be more practical to represent the individual areas and their respective variants in the documentation in the form of partial models. In combination, these partial models of the different areas then yield a specific variant of the overall model. For the presentation of further variants, the partial models can be removed and substituted as required. Thought through to its logical conclusion, this suggests that it may make sense (for this and other reasons) to have the same structure in the documentation and the model, i.e., the designation and structure of the areas in the documentation correspond to those in the modelling software. This would also make it possible to import the layer structure from the modelling software into IDOVIR and to automatically generate or update the structure of the areas and time frames – an additional incentive to lay down a sensible layer structure in the modelling software, which does not always happen in practice.

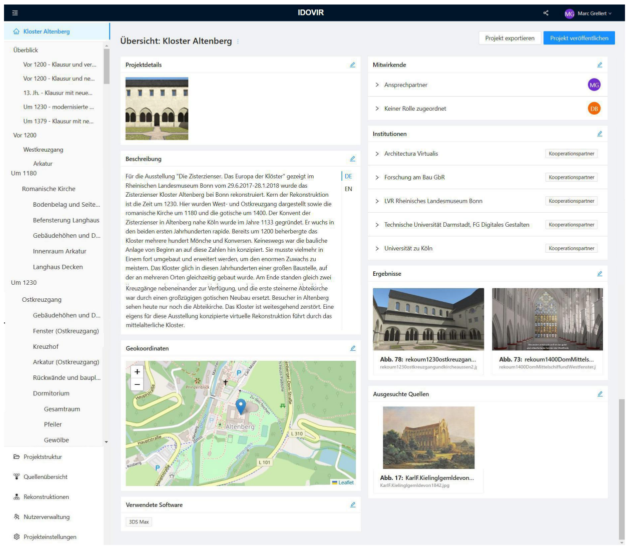

Fig. 3. IDOVIR user interface with a project overview including the project structure (left).

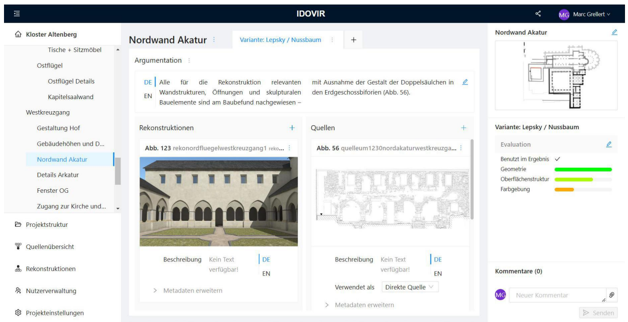

Fig. 4. Presentation of a variant of an area with reconstruction, sources and argumentation.

IV. EVALUATION OF RECONSTRUCTION RESULTS

A reconstruction process almost always entails the interpretation and evaluation of sources to provide a starting point for the creation of a (hypothetical) model. The plausibility of the reconstruction result depends not only on the informational value and nature of the sources used but also on subjective, conscious or unconscious decision-making processes, such as, for example, stylistic or aesthetic preferences. The evaluation of plausibility can therefore never be purely objective. Nevertheless, a subjective evaluation of a reconstruction can contribute to the assessment of the plausibility of the results or partial results. How such an assessment can be made and communicated has already been the subject of several studies that also include various structuring and communication strategies [19, 17, 18, 20].

In IDOVIR, the evaluation consists of three categories. It combines the option of self-evaluation with regard to the (subjective) assessment of the plausibility of the reconstruction with an (objective) classification of the sources used. Corresponding to the structural division into areas, the evaluation refers to a single area of a reconstruction, for example the area "west façade".

The first two categories refer to the sources used. In the first category, a used source is classified according to its type. The following subdivision was developed in collaboration with Fabrizio Apollonio [25]:

- Architectural survey
  - Laser scan and/or SfM of architectural remains
  - Survey drawing
  - Photography
- Design
  - Final design
  - Initial design
  - Final maquette
  - Initial maquette
- Abstraction
  - Illustrative model
  - Drawn reconstruction
  - Reconstruction model
  - Contemporary drawing / sketch / painting
  - Relief / seal / coin / medal
  - Written / oral description

Here, the classification is usually unambiguous and made by the user while entering the source. Since sources are supplied for the entire project and remain available in a global directory, the type of source always remains the same. The automatic evaluation then shows which type of source occurs with which percentage frequency in the reconstruction of the corresponding area. The representation is shown in a bar chart (Fig. 5).

The second category establishes the relation of the source to the reconstruction. It indicates whether the

Fig. 5. Classification of sources according to type and relationship to the reconstruction.

source describes the reconstructed object itself or whether the source represents (merely) an analogy. The following subdivision is proposed here:

- Direct source
- Analogy to the object
- Analogy to another building / complex
- Analogy to a constructive / technical system
- Analogy to an idea

The third category is an assessment by the user of the plausibility of the reconstruction of an area subdivided into:

- Geometry
- Surface structure
- Colouring

It is possible to enter a rating for each of these three subsets. The user may take a default setting, which is structured as follows:

- Fictional
- Based on analogies
- Partly substantiated
- Largely substantiated

However, users are free to select both the name and the number themselves, for example purely numerically (e.g. 1-6 or less or more).

The evaluation is represented by a pie chart, in which the portion of the circle that is filled in rises with the user's confidence in the plausibility of the reconstruction (Fig. 6).

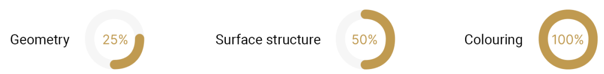

Fig. 6. Graphical summary of the evaluation of the reconstruction.

V. CONCLUSION

The sound documentation of virtual, hypothetical architectural reconstructions is an essential prerequisite for any scholarly debate. It has to record not only the sources that were used but also the interpretation and decision-making processes that finally led to the reconstruction result.

IDOVIR is a platform that allows reconstruction projects to be documented easily and customisably. A freely configurable structural organisation into spatial areas and time periods is designed to meet the individual and specific requirements of a wide range of projects. The classification of sources and the evaluation of (partial) results permit an overview and insight into plausibility and informational value. However, the discussion about how to present plausibility in a meaningful way in computer reconstructions is still in its early stages. IDOVIR makes a proposal for this. Feedback from the expert community is needed and welcome.

IDOVIR has been available online (https://idovir.com/) since January 2023 and has been constantly updated since then. It not only provides free, low-threshold access for everyone, it also allows for cross-institutional collaboration. Data entry and publication follows the FAIR principles. It is intended to disclose the source code of the platform at the end of the current funding phase and thus facilitate collaborative further development. The fact that the platform is operated in collaboration with the Universitäts- und Landesbibliothek Darmstadt ensures its long-term sustainable provision.

The future goal is to make IDOVIR more widely known and established in the specialist community. A broader acceptance and willingness to use it is to be achieved by additional support of the workflows by means of automated data entry and transfer as well as by offering further target group-oriented tools. At the same time, more people involved in reconstructions have to be made aware of the need for documentation. To achieve this, colleges and universities that perform virtual reconstructions have to be contacted and convinced of the value of IDOVIR in teaching. A similarly targeted approach is needed to reach institutions and individuals who commission reconstructions. Contact should also be made with practitioners of related disciplines such as archaeology and heritage management to determine their views and needs in the context of virtual reconstructions, and to see how they can be served by what is already covered by IDOVIR and what synergies can be exploited to benefit from the knowledge of the respective disciplines.

Another desideratum is the pooling of information and metadata on the entered data that are distributed across different locations. To date, these have been entered redundantly or copied repeatedly by the users, which takes a considerable amount of time and often represents a significant barrier to the use of documentation solutions [1]. Therefore, a service is to be developed that collects and collates this interrelated information, suggests it to the user and makes it available for easy transfer, while offering correction options. (Semi-)automated data retrieval from Open Data repositories (e.g. Digitale Deutsche Bibliothek, Europeana, Wikidata, etc.) would allow for the verification and supplementation of these metadata, which, in turn, would lead to shorter workflows.

To make documentation even more efficient, timesaving and intuitive, workflows as well as communication functions of IDOVIR will be improved in the future. An important component of future development is therefore the improvement of the correlation and comparison of sources and reconstruction results. This should not only provide an important basis for discussions and evaluations but also facilitate the identification of inconsistencies in the sources and the detection of contradictions in the reconstruction solutions. This should be made possible by a kind of light table (canvas) on which several sources or reconstruction views (2D or 3D) can be flexibly arranged, without losing any metadata links and while maintaining the ability of accessing the corresponding entries.

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