Linked Data in a 3D Context: Experiential Interfaces for Exploring the Interconnections of 17th-Century Historical Data

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Within the *Virtual Interiors* project[1] various Amsterdam houses are reconstructed in three dimensions based on historical research. One of the case studies is the house of 17th-century Amsterdam-born patrician Pieter de Graeff and his wife Jacoba Bicker. The interdisciplinary dataset resulting from this case study (detailed in Piccoli, 2021) is presented within an online 3D research environment, which also serves as a starting point for further exploration of historical data[2]. In earlier work (Huurdeman & Piccoli, 2021), we described this as a three-step process model of knowledge creation, sharing and discovery: new insights emerge during the creation of the 3D reconstructions (1), these insights are shared via an online research environment (2) and users may discover new knowledge through interacting with the environment and additional Linked Data (3). This paper focuses on the third step, the integration of related Linked Data relevant for Humanities researchers in a 3D research environment.

Linked Data is used to achieve the vision of the "Semantic Web", in which data is represented in a form that is more universal, directly interconnectable and "more easily machine-processable" (Antoniou & Van Harmelen, 2008). Linked Data uses uniform identifiers (URIs), which can easily be looked up, and utilizes open standards, such as the data model RDF and query language SPARQL (Berners-Lee, 2009). In the last decade, various projects have modeled and created historical Linked Data related to the Low Countries (see for instance De Boer et al. (2016), Meroño-Peñuela et al. (2020) and Zamborlini (2017)). However, examples of directly using Linked Data in the context of 3D reconstructions are quite scarce (see e.g. Kuroczyński et al. (2016), Kuroczyński (2017) and Yu & Hunter (2013)). The Virtual Interiors research environment integrates Linked Data to retrieve external biographical information and additional resources related to the objects that are present in the 3D reconstructions, their makers and the subjects they depict.

Datasets created within *Virtual Interiors* (see Piccoli, 2021) include annotated transcriptions of Pieter de Graeff's almanacs, the probate inventory drawn up after his death, and metadata and paradata connected to the 3D reconstructions. These datasets use the uniform identifiers of other Linked Data to retrieve external information related to the 3D reconstructions, for instance URIs representing concepts within the Art and Architecture Thesaurus (AAT)[3] and persons in Ecartico[4]. The Ecartico URIs in the metadata make it possible to

[1] http://www.virtualinteriorsproject.nl (last accessed May 2021)
[2] An interactive demo of this research environment will be made available during the DH Benelux conference. For a screencast of the prototype, see: https://dx.doi.org/10.21942/uva.14424218 (last accessed May 2021)
[3] The AAT contains a large variety of concepts related to art and visual works, such as work types, roles, materials, styles, cultures, techniques, and subjects, see: https://www.getty.edu/research/tools/vocabularies/aat (last accessed May 2021)
[4] Ecartico is a large collection of structured biographical data on individuals involved in the cultural industries in the early modern Low Countries (e.g. painters, printers and booksellers), see: http://www.vondel.humanities.uva.nl/ecartico/ (last accessed May 2021)

retrieve and display biographical information about an artist without modeling or storing this data ourselves. Further, the prototype directly brings in and visualizes related[5] resources based on the included URIs, such as works included in Wikidata[6], Adamlink[7] and the Golden Agents Linked Data repository[8].

We argue that these kinds of datasets can serve as natural extensions to the datasets created in *Virtual Interiors*. By directly integrating related resources in our research environment, combined with information about their provenance, we enable further content exploration for humanities scholars. This allows for *discovery* of new knowledge and relations – the third step of our process model. For instance, a researcher can select the bas-relief sculptures of the parents of Pieter de Graeff within the 3D environment (Figure 1), and browse other image galleries of artworks sharing the same portrayed relatives, or sculptures made out of the same material from other collections. These image galleries are generated based on editable Linked Data queries[9] (Figure 2). By integrating visual examples, we aim to trigger potentially unexpected and serendipitous encounters (McCay-Peet & Toms, 2015). Moreover, it is possible to *compare* items found in the prototype with related items outside the 3D reconstruction. For instance, how do the bas-relief sculptures by Artus Quellinus compare with other sculptures in the same timeframe created in different geographic areas. Finally, using the functionality to save relevant items, it is possible to *collect* and annotate a set of items for further study[10].

The online research environment prototype has been created as a multi-layer interface (Shneiderman, 2003; Huurdeman & Piccoli, 2021), aiming to support first-time, intermittent and expert users without creating an overly complex user interface. First, an "analytical" user interface layer aims at scholarly use via desktop platforms or tablets, and includes all reconstruction details, uncertainties, and annotation possibilities (Figure 1 & 2). The second "experiential" interface layer provides a more immersive experience (Dede, 2009), where both casual users and researchers can explore the physical space and examine objects, for instance via the motion sensors of mobile phones and by physically moving around wearing a Virtual Reality headset (Figure 3). Related resources are retrieved using the same underlying Linked Data queries as in the analytical interface, but projected around the user's viewpoint in three dimensions[11].

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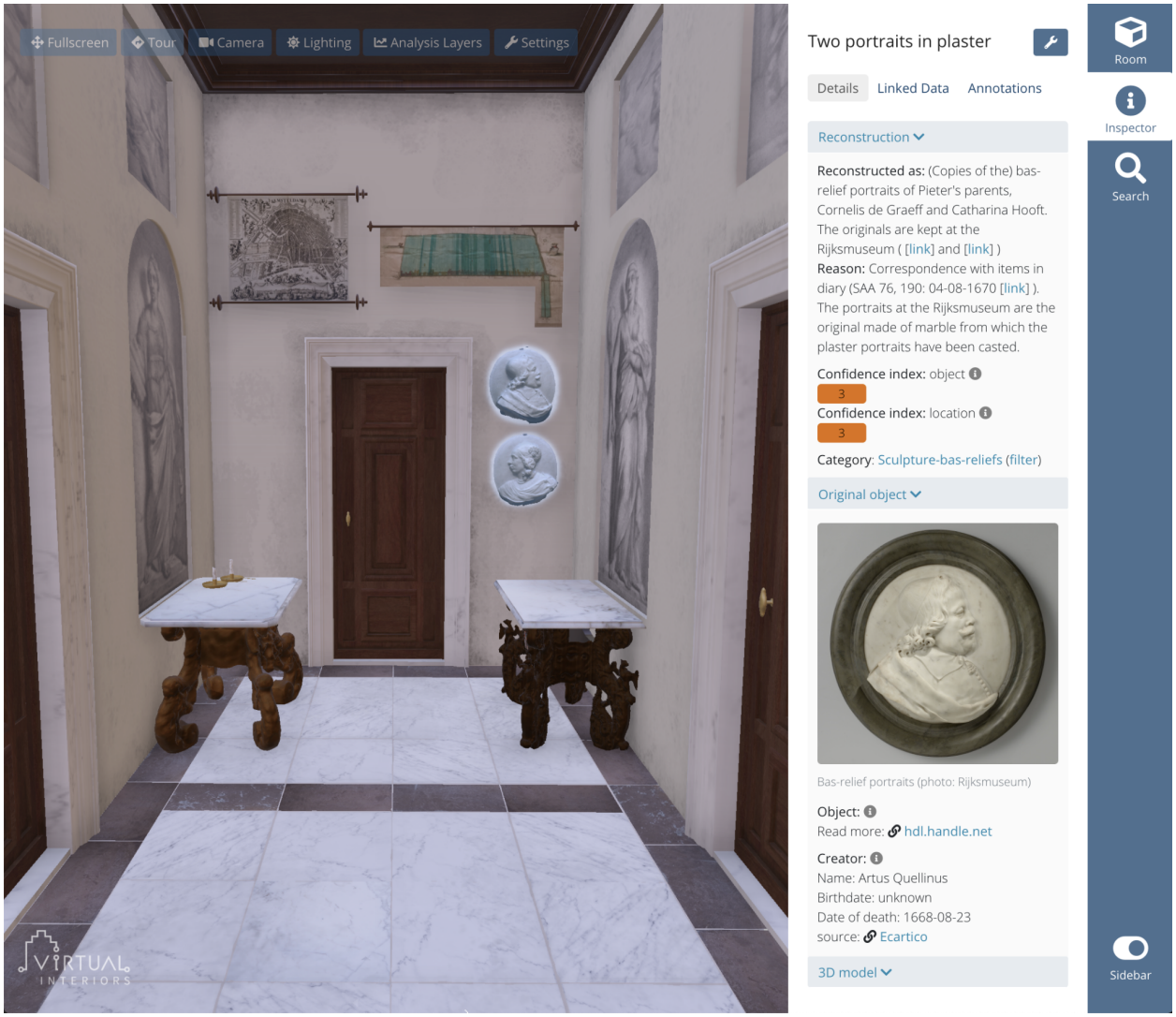
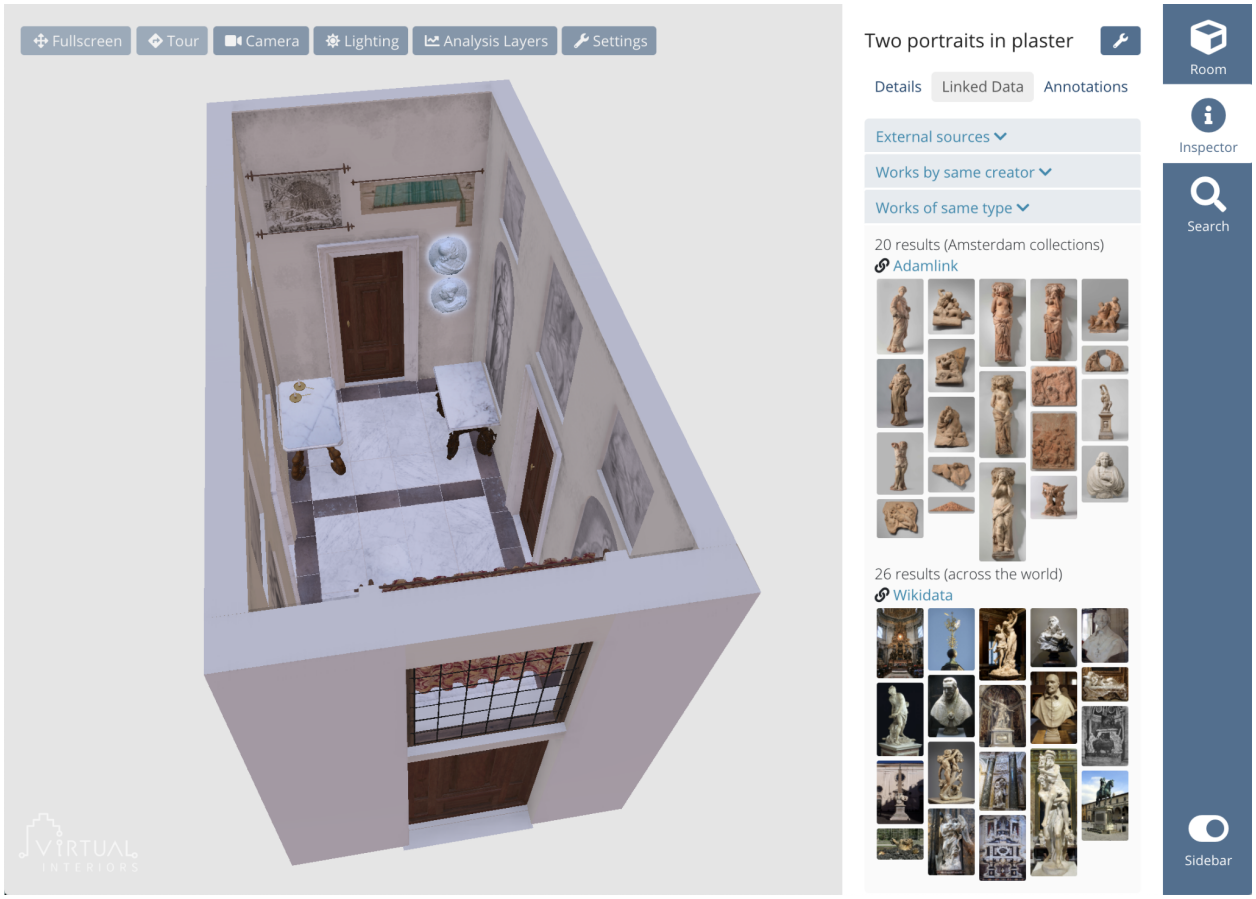
[5] "Related" can be interpreted in various ways, for instance a work created by the same artist, from the same time period, having the same AAT category, and so forth.
[6] Via https://www.wikidata.org/ (last accessed May 2021)
[7] Via Druid: https://druid.datalegend.net/AdamNet/all (last accessed May 2021). More information: https://adamlink.nl/ (last accessed May 2021)
[8] Within Golden Agents, a sustainable research infrastructure is created "to study relations and interactions between producers and consumers of creative goods" (https://www.goldenagents.org/, last accessed May 2021). Linked Data and semantic web technologies are utilized to reach these goals and to connect a number of heterogeneous datasets (see https://data.goldenagents.org/ last accessed May 2021). These datasets include archive sources from the Amsterdam City Archives, such as notarial deeds, baptism, marriage and burial registries (see Van Wissen et al., 2021 for a discussion of the ROAR++ ontology for archival resources), and works from the collections of the Rijksmuseum. Within the Virtual Interiors 3D research environment, we directly incorporate Linked Data from Golden Agents, and our datasets will also be made available via Golden Agents when the project ends.
[9] SPARQL queries, stored in a format compatible with https://grlc.io (last accessed May 2021).
[10] These concepts align with the scholarly primitives *discovering*, *comparing* and *collecting* suggested by Blanke & Hedges (2013) in the context of research infrastructures.
[11] Using cylindrical projections, as well as structural features within the 3D space such as walls.

This paper summarizes the experiences of utilizing Linked Data within the Humanities as extensions of created datasets in novel analytical and experiential interfaces based on 3D reconstructions. We discuss opportunities and pitfalls, from the perspective of the data, including data availability and quality, and from the perspective of integrating this data into user interfaces allowing for knowledge discovery. Further, we demonstrate the current research environment prototype, which is fully functional and provides flexibility by allowing for visualizing different datasets and 3D models[12]. In addition, we discuss the initial findings of a user study in which Humanities researchers directly explore these user interfaces, leading to further insights into their potential for knowledge discovery.

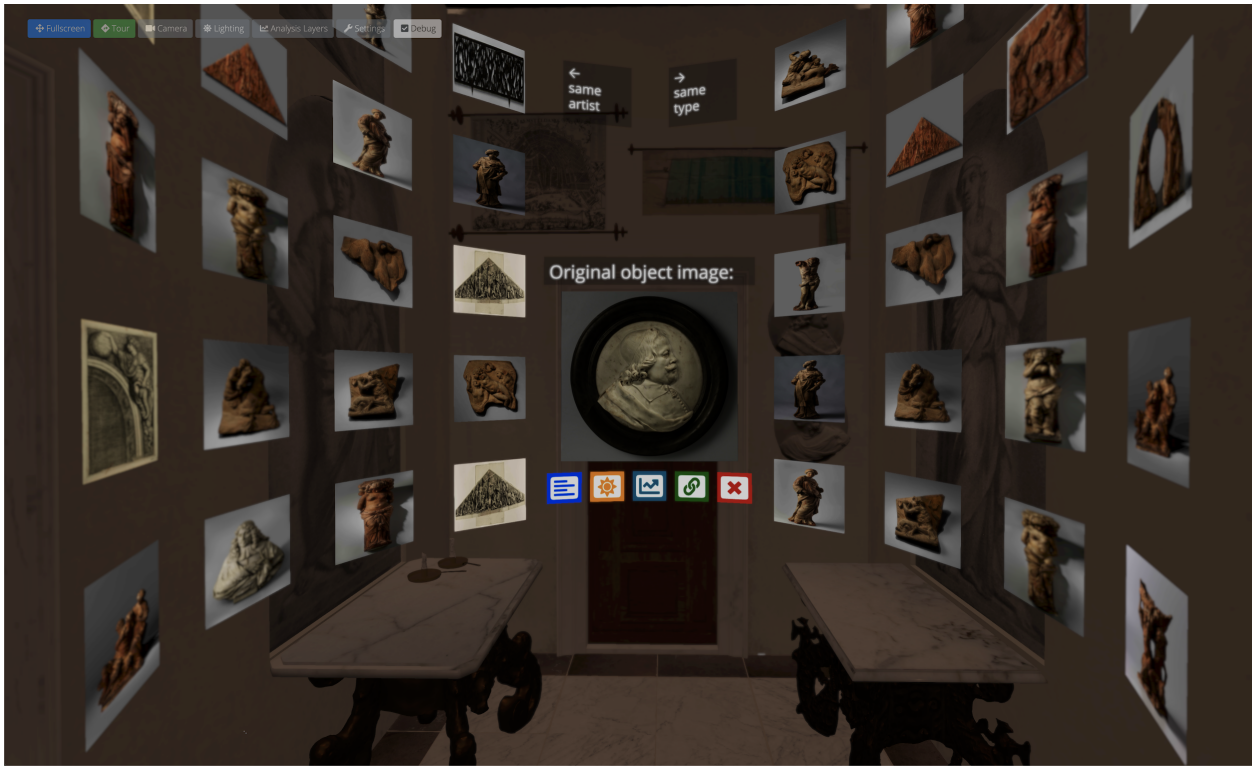
[12] Namely, the prototype already allows for visualizing the 3D reconstructions and dataset discussed in this paper (see Piccoli, 2021); 3D models from the earlier "Digital Drawings" project (Huurdeman et al., in prep.); and a sample application related to visualizing audiovisual collections (see Huurdeman & De Vos, 2020).



[Figure 1] Screenshot of the Virtual Interiors analytical interface prototype on a desktop computer, showing an interactive first-person view of the entrance hall of De Graeff's house, with the copies of Quellinus' portraits selected. In the sidebar panel, reconstruction details can be viewed (including explanations and uncertainties), as well as the details about the original object the reconstruction is based on. This screenshot also shows how related biographical data from Ecartico is directly integrated into the interface.



[Figure 2] Screenshot of the Virtual Interiors analytical interface prototype, "orbit" view. Quellinus' portraits are selected, and the "Linked Data" tab in the sidebar has been opened. Related thumbnails of artworks of the same type (i.e. sculptures) from other collections (1600-1700) are depicted. The Linked Data queries these views are based on can be optionally edited and extended by the user.



[Figure 3] Virtual Reality screenshot of the experiential interface. Quellinus' portraits have been selected and the Linked Data display activated. A cylindrical projection shows works from the same artist in Adamnet on the left-hand side, and other sculptures from Adamnet on the right-hand side.

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