“More than just a Picture” – The Importance of Context in Search User Interfaces for Three-Dimensional Content

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ABSTRACT

While searching for two-dimensional content has become common practice in our work and leisure activities, search and retrieval of three-dimensional assets has thus far been underrepresented in research and practice. Therefore, it is unclear how to exactly support complex searches for these types of content. To contribute to fill this gap, this paper focuses on the role of context in Search User Interfaces (SUIs) for 3D objects and shows how it is envisioned by digital humanists in an exploratory user study. An evaluation of interactive mockups of a prospective search engine, contextualized by 2D, enhanced 2D and 3D maps, shows the scholars' preference for three-dimensional map views. A further qualitative analysis also suggests the need for more hybrid ways to visualize spatial context of 3D objects. This includes object properties, object relationships and spatial cues. Our findings contribute to a better understanding of SUI support for accessing the growing number of reality-based 3D models and virtual reconstructions.

KEYWORDS

search user interfaces, 3D objects, digital humanities, user studies

ACM Reference Format:

Hugo C. Huurdeman and Chiara Piccoli. 2020. “More than just a Picture” – The Importance of Context in Search User Interfaces for Three-Dimensional Content. In *2020 Conference on Human Information Interaction and Retrieval (CHIIR '20), March 14–18, 2020, Vancouver, BC, Canada.* ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/3343413.3377994

1 INTRODUCTION

In current, transnational projects, such as Time Machine[1], a considerable number of historical environments are reconstructed in three dimensions. Specifically, within the Virtual Interiors[2] project, various Amsterdam historical houses are reconstructed in a virtual environment, which includes references to contextual information and the level of uncertainty in the proposed 3D model. The case study we are focusing on in this paper is the house of Pieter de Graeff, a 17th century Amsterdam regent. An inventory lists almost 1,000 objects located in the house, of which a selection has been modeled in 3D and placed in its (reconstructed) historical domestic context. These 3D reconstructions, as well as an increasing number of reality-based 3D models and virtual reconstructions created in the context of other projects[3], provide ample new ways for researching and experiencing historical environments – for audiences ranging from the casually interested to specialized scholars.

One largely overlooked aspect in research and practice is however how to create suitable platforms and interfaces which support the search and retrieval of these 3D models. In the field of cultural heritage, examples are still rare. In the context of Europeana and 3D-COFORM, for instance, attempts have been made to develop text-based or shaped-based approaches to query 3D cultural heritage[4]. One recent example of a prototype for 3D search in the archaeological domain is the QueryArch3D tool which allowed users to search and query segmented reality-based and computer-aided design 3D models of a Mayan archaeological site located at Copan, Honduras [1, 2, 38]. Common ways to explore and experience 3D virtual environments include first person views – moving around in the environment – and third person “orbit” views, which can be freely rotated[5]. In our case, however, the number of 3D objects amount to hundreds, and access via complex 3D engines may not be straightforward for the rich variety of potential audiences, including scholars (see e.g. the orientation issues discussed in [15]). For this reason, we explore search as an access method. This paper explores the role of context in Search User Interfaces (SUIs) and evaluates approaches to contextualize search for historical 3D objects, via an exploratory user study with six digital humanities scholars, using qualitative and quantitative methods. We look at three research questions:

- RQ1 How do digital humanities researchers conceptualize or visualize search result lists for 3D objects in the context of historical 3D reconstructions?
- RQ2 Which type of spatial support in the form of 2D, enhanced 2D and 3D maps is preferred by digital humanities researchers in the context of exploratory searching for 3D objects?
- RQ3 Which dimensions of spatial context do digital humanities researchers refer to within the scope of searching for 3D objects?

2 PREVIOUS LITERATURE

The emerging field of digital humanities involves “humanities scholars' increasing use and exploration of information technology as both a scholastic tool and a cultural object in need of analysis” [33].

[1]timemachine.eu
[2]virtualinteriorsproject.nl

[3]Projects related to the creation and archiving of 3D models in a CH context include EPOCH, 3D-COFORM, CARARE and 3D-ICONS, and organizations such as Europeana (see e.g. pro.europeana.eu/project/advanced-documentation-of-3d-digital-assets/).
[4]See e.g. pro.europeana.eu/data/assets3d-search
[5]E.g. used by sketchfab.com. For an in-depth list of 3D interaction techniques, see [23].

CHIIR '20, March 14–18, 2020, Vancouver, BC, Canada

ACM ISBN 978-1-4503-6892-6/20/03…$15.00
https://doi.org/10.1145/3343413.3377994

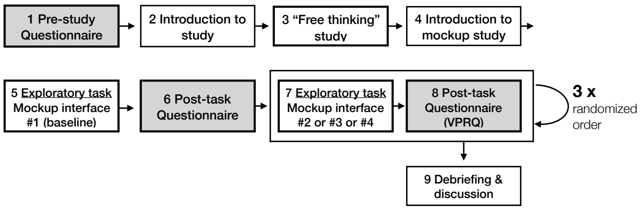

Figure 1: (Simplified) study protocol.

Research tasks conducted by scholars, including digital humanists, generally can be classified as cognitively complex work tasks [21, p.20], as defined in the field of information seeking and retrieval. Within these complex tasks "understanding, sense-making, and problem formulation are essential, and require different types and more complex types of information" [9]. This information may be increasingly acquired via search systems. The main purpose of such *interactive information retrieval* (IIR) systems is "to deliver task-specific information that leads to problem resolution," as Toms [35] has suggested. A variety of literature has looked at the information seeking behavior [42] of scholars within different subdisciplines of the humanities, as described by e.g. [3, 4, 7, 8, 12, 16, 28, 31, 36], and summarized by [10, p.297-301]. This understanding might help us in designing search systems and their user interfaces [37, 40].

SUIs, the 'front-end' to search systems, play a key role in supporting complex and research-based tasks: they aid users in expressing their needs, in formulating their queries, understanding the results and in keeping track of their progress [19]. In this paper, we look at SUIs in the context of working with intrinsically complex 3D environments. A variety of strategies for querying 3D content can be devised. Previous literature suggests five broader categories of query methods: queries using text (e.g. [18, 25]), using 2D sketches [18, 25], using 3D shapes and 3D objects [18, 27, 32, 34], queries issued from the 3D environment itself (e.g. [17]), and multimodal queries [18]. In this paper, we focus on textual queries, since our collections have a large amount of contextual information in textual form, and because of study participants' familiarity with text-based searches. In terms of search result presentation, ample discussion has taken place on moving beyond 2D representations. The use of 3D representations of results has been a contentious issue. As Hearst [19] indicates, for information processing tasks, "3D has been found to be inferior, or at best equivalent to 2D or textual interfaces when usability comparisons are done." This might be related to the "additional overhead" needed for interaction with these 3D spaces [41]. However, many of the 3D search and browsing interfaces discussed in previous literature (e.g. [11, 14, 19]) were focused on intrinsic 2D content, which might have less benefits when presented in 3D. A study combining hypertext and 3D contents [22] showed benefits of using a dual-mode 2D/3D interface for 3D exhibition contents. In a study on user satisfaction and preferences concerning 2D and 3D product representations [26], it was found that participants had a preference for 3D representations in terms of their details, ease of use and presented amount of information. Since little prior user-oriented research is available about SUIs for 3D content (often with a technical focus, e.g. [25]), we take related studies [22, 26], and a study on search visualizations [13] as an inspiration for designing and evaluating contextual search support.

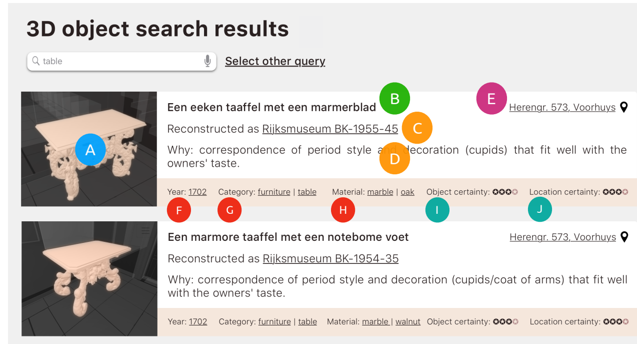

Figure 2: Baseline SUI (first 2 results). Result item: Ⓐ 3D model thumbnail. From archival info.: Ⓑ Title; Ⓒ-Ⓓ descriptions; Ⓔ house address, room; Ⓕ-Ⓗ various metadata. Ⓘ-Ⓙ Degree of uncertainty in proposed 3D reconstruction.

3 SETUP AND METHOD

We conducted a formative and exploratory user study, using interactive mockups representing different interface variants.

Participants Six junior and senior digital humanities researchers employed at the University of Amsterdam participated in the study. Three participants had an MA degree, one was doing a PhD, one was a post-doc and one a full professor. The majority of participants (4) were aged between 25-34. All participants were specifically involved in various digital humanities projects and had a background in the humanities, more specifically (art) history, digital heritage, and Dutch Studies. Experience with 3D sources and environments ranged from no use at all (1 participant), to monthly (3), weekly (1) and daily use (1). Study sessions lasted between 60 and 90 minutes.

Interface For the user study, four mockups were created in Sketch[6]. Each of these used the real data available in the project (hence, 3D models, descriptions, archival information and further specific metadata). Each mockup contained a search box, and results lists of four common queries using this data ('table', 'furniture', 'art' and 'map'). The included 2D and 3D maps were generated as images using a prototype viewer for the 3D models created by one of the paper authors. The mockups were exported as HTML pages and were fully interactive – participants could click on various metadata elements and on the available maps[7]. Screenshots and details about the baseline and map interfaces are presented in Figure 2 and 3.

Study and task design The study used a think-aloud protocol and an exploratory simulated work task [5], which the participants could relate to due to their background in digital humanities[8]. Figure 1 summarizes the various parts of the study[9], which included a pre-questionnaire, a 'Free thinking' study of an envisioned search engine for historical 3D objects, as well as the use of interactive mockups serving as a baseline (Fig. 2). Then, three additional mockup interface conditions with three contextual map variants

[6]sketchapp.com, combined with plug-in: github.com/ingrammicro/puzzle-publisher/
[7]Mockups and other resources: github.com/timelessfuture/virtual-interiors-search/
[8]Task: 'Imagine you have selected the [case study house] from a virtual map of 17th century Amsterdam, and you are interested in exploring 3D objects in his house for a research project (in an early and exploratory stage) – potentially leading to a paper.'
[9]This study aimed to take a holistic look at search in a 3D context. This short paper reports on part #3, 5, 7 and 8 (Fig. 1), further parts will be described in future work.

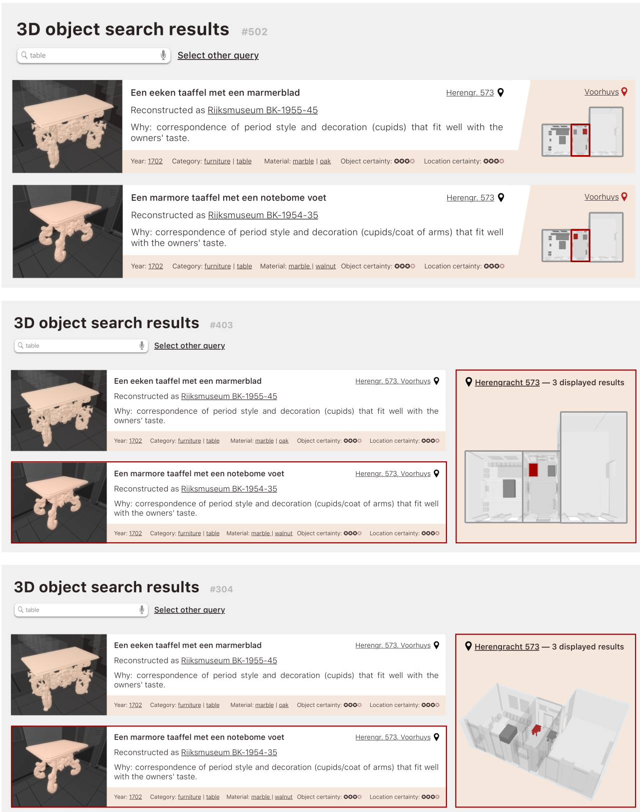

Figure 3: Evaluated variant map interfaces (top to bottom): ① *2D-S*, small 2D maps, same as baseline interface (Fig. 2), but with static per-result maps, highlighting object location in red.
② *2D-XL*, large 2D map, combined results. Click on object in map highlights a result item in red, and vice versa.[10]
③ *3D*, large 3D map, combined results. Interactivity same as interface ②, but with 3D perspective map.

were evaluated (Fig. 3), followed by corresponding post-task Visual Product Representation Questionnaires (VPRQ), adapted from [26]. Each participant had a different sequence of the three variant interfaces out of the six possible orders, to mitigate order effects.

Data collection & analysis This study used qualitative and quantitative methods. Observation notes were taken, and audio and screen recordings were made. ***RQ1*** provides a qualitative look at transcribed audio recordings (using ELAN [30]), for the 'free thinking' study part (Fig. 1 #3). ***RQ2*** focuses on a quantitative analysis of responses to 10 questions included in all 3 VPRQ post-questionnaires (Fig. 1 #8), with contextual qualitative examples from think-aloud transcripts of corresponding sessions. For ***RQ3***, thematic analysis [29] was done by one of the paper authors, based on the think-aloud transcripts from different parts of the study (Fig. 1 #3,5,7) – iteratively following the steps from [6][11]. The codebook and resulting themes were cross-checked by both paper authors and subsequently refined.

[10]Behavior inspired by ResultMap visualization in [13].

[11]i.e. familiarisation, initial code generation, search for themes based on initial codes, review of themes and the write-up of the analysis [6]. We took an inductive approach.

4 FINDINGS

4.1 RQ1: Conceptualizing a 3D search engine

In the first part of our study, participants were asked about which queries they would issue in a search engine for 3D objects in the context of a search engine of a reconstructed house, and how they imagined search result display. Queries mentioned by participants were commonly related to (tangible) objects, such as furniture ('bed', 'chair', 'table'), as well as art ('painting', 'art'). With respect to results display, participants imagined seeing textual and list-related aspects, for instance "a list of paintings that were in the house" (P02) – which might be ordered by house, room or number of items (P06). Further metadata elements were discussed, such as a description of an item, links to sources, and enrichments (P06). Also, aspects important to the research process were mentioned, such as listing assumptions (P04) and sources (P04, P06) – this way, as P04 asserted, "nothing is behind the scenes – in the black box".

On the visual side, participants imagined depictions of the reconstructed house, hence "some kind of image" which is "visually attractive" to know "what things look like" (P06). For instance, in the form of the "model or representation of the model with hotspots" (P01), or a semi-transparent house with highlights (P04). As P02 put it, one should "not just get the image", but also the larger spatial and historical context. Hence, a clear emphasis on *context* could be observed, for instance "where something is", but also "how it relates to other objects and environments" (P03).

4.2 RQ2: Comparing 2D and 3D map variants

To understand the role of context better, we now discuss the comparative evaluation of three concrete ways to augment SUIs with visual map depictions of reconstructed rooms (Fig. 3). Results from the VPRQ post-questionnaires, presented in Table 1, but also participants' remarks during the study, suggest a clear user preference for the 3D maps. For satisfaction (Table 1, Question A), the 3D map had an average rating of 4.167 on a 5-point Likert scale – closely followed by the 2D-XL map (3.833). The 2D-S map, on the other hand, had a lower satisfaction rating (3). This is reinforced by the largely positive remarks of participants during the think-aloud session: indicating that it is "much clearer" than 2D representations (P02), and that it "gives a better perception of space" (P02). Three participants (P03, P05, P06) indicated that this type of representation was "what they imagined before". According to the post-questionnaire, the 3D map also gives a better impression of objects' locations (D) than the other types – for instance due to the angle (P01). The 3D map gave a more adequate information to judge the 3D object (C), with a rating of 4.167 instead of the rating of 3.167 and 3 for the 2D maps. In addition, the overall understanding (N) was better for the 3D map than both other map types, which performed similarly.

Both the enhanced 2D and the 3D map received a much higher rating of 4 for having adequate interaction (K), for instance seen as being "good fun to explore" (P04). The rating for the small 2D maps is lower: only 2. Hence, as P02 put it, "it would be nice if the [2D map] was somewhat more interactive". Thus, as reverse question Q confirms, more features are desired in the case of the 2D maps.

Finally, the results of the survey, as well as participants' comments also suggest a need for a combination of map modalities. The average score on whether a particular map type is enough in itself

Table 1: VPRQ questionnaire results, 5 pt. Likert scale scores

Question ID, text	2D-S average (s.dev)	2DXL average (s.dev)	3D average (s.dev)
A. I was overall satisfied with the [map type] maps of the objects in the collection.	3 *(0.89)*	3.83 *(0.98)*	4.17 *(1.17)*
C. I thought the inf. I received from the maps was adequate for me to judge the 3D object.	3 *(0.89)*	3.17 *(1.17)*	4.17 *(0.98)*
D. I had a good impression of the objects' location from the maps.	3.5 *(1.38)*	3 *(0.63)*	4 *(1.55)*
I. I think the inf. I received from the [map type] of the object locations was accurate.	3.5 *(0.55)*	4.5 *(0.84)*	4.33 *(0.52)*
J. I spent substantial time exploring the maps.	2.33 *(1.03)*	4 *(0)*	3.83 *(0.75)*
K. I think the maps allowed an adequate interaction between me and the object.	2 *(1.10)*	4 *(1.10)*	4 *(0.85)*
L. The maps were easy to observe.	4 *(0.89)*	3.67 *(1.51)*	4.33 *(0.82)*
N. After these tasks my overall understanding of the objects has improved.	3.5 *(0.55)*	3.5 *(1.23)*	4 *(0.63)*
Q. I think the features of these maps were inadequate; there should have been more features embedded onto the maps. (reverse)	4 *(1.10)*	2.67 *(1.51)*	2.67 *(1.21)*
W. I think all visual map representations should be [map type].	1.67 *(1.67)*	2.5 *(1.05)*	2.5 *(1.05)*

(W), is very low for the 2D-S maps, but also below average for the 2D-XL and 3D maps. Participants P02-03, P05 and P06 suggested potential combinations – e.g., a larger map overlay upon clicking on a small map. P04 pointed towards combinations of maps depending on (research) task: the 2D-XL map for object locations within a room, and the 3D map for locations within the whole house.

4.3 RQ3: The role of spatial context

In our analysis so far, RQ1 has shown the importance of context, and RQ2 suggested which spatial support potentially works best. Here, we zoom in further to the exact role of *spatial context*. Table 2 shows the results of our thematic analysis of think-aloud transcripts, in which we subdivided spatial context into three specific subthemes[12].

First, *object properties* refers to locations and size of objects. The location of objects was mentioned by all participants, reflecting its importance. Furthermore, the size, proportions and shapes of objects were referred to by four of the participants – for instance the flatness of paintings causing a challenge in 3D representations (P03,05), the relative size of objects within a space (P03), or the inability to see some objects' real size in a 2D representation (P06).

Second, *object relationships* came up frequently in the think-aloud sessions: the relationships of objects with other objects, or with their environment. All participants mentioned the ability and sometimes inability to view adjacent objects, e.g. to view an object that is located next to an object shown in the results list. In particular, the vertical distance can be hard to judge in two-dimensional representations (e.g., a map above a painting, or a sculpture above a door). One participant (P04) wished to see the locations of similar objects in different areas of the house. Also, research interests in

[12]Our thematic analysis of think-aloud transcripts initially resulted in 7 themes. The 3 most common themes were: *spatial context* (145 occurrences), *map visualization* (138) and *specific implementation issues* (115). Here, we report on spatial context.

Table 2: Derived spatial context themes from transcripts

Spatial context subthemes	Participant #
object properties	
- *generic*	*P02-03*
- location of object(s) in house / area / room	P01-06
- size / proportions / shape of object(s)	P03-06
object relationships	
- *generic*	*P04*
- adjacent objects (e.g. horiz. / vertically positioned)	P01-03, P05-06
- similar objects	P04
- object relation to surrounding environment	P03-P06
perception of space	
- *generic*	*P02-04, P06*
- proportions and contents of house / area / room	P01, P03, P05-06
- structural elements in house (e.g. fireplace)	P01-02, P04
- room / area locations, names and functions	P02, P04-06
- lighting	P06

relationships of objects with their environment were mentioned frequently (P03-06) – for instance, some types of objects might be placed close to a window, or far from an entrance to a room, in some parts of the house, or close to certain other objects.

Finally, *perception of space*, including proportions, structural elements, space functions and lighting, was mentioned in various ways. This includes the ability to judge the proportions of the house and subsections of the house (P01,03,05-06) – for instance, getting an idea of the size of a room (P03). The importance of structural elements within a house and room was mentioned by three participants (e.g. fireplaces, doors, windows and staircases). Also, rooms and areas were alluded to frequently, in terms of providing clear indications about their locations, names and functions.

5 DISCUSSION AND CONCLUSION

In our exploratory user study of enhanced search for 3D objects from historical reconstructions, we observed the prime role of context in retrieving historical 3D objects, and a preference for 3D map visualizations of historical houses, as compared to small and large 2D maps. Our thematic analysis also suggests further hybrid ways to visualize spatial context of 3D objects, incorporating object properties, their relationships and perception of space.

Our findings, while based on an initial set of participants, have implications for the thus far underexposed design of search systems for 3D content. First of all, it is of key importance to integrate ways in SUIs to provide "more than just a picture". Spatial context is crucial, may be supported by visualizations, and our categorization of needs for spatial context might serve as an outline for the functionality and design of future solutions. Furthermore, since search systems are familiar to a wide audience, search could be combined with map displays as an easier entry point to access 3D objects and environments, potentially triggering further exploration. In future work, we will expand test user groups, evaluate needs for research stages beyond exploratory phases [20, 24, 39], and construct hybrid prototypes combining search and actual 3D environments.

ACKNOWLEDGMENTS

The authors wish to thank all study participants. This research was supported by NWO (Virtual Interiors, # 314.99.302).

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