Data Visualization via Enhanced Maps in a Digital Humanities Context – a Design Perspective

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Introduction

In the past decades, geographical maps have been used extensively as a means for spatial data visualization in the Humanities and beyond. Here, we consider data visualization to be the "representation and presentation of data to facilitate understanding" (Kirk, 2019). While maps have myriad advantages for visualization, such as presenting the spatial distribution of data to potentially generate new insights, they are also are inherently abstractions of reality. This abstraction can raise issues (see e.g. Allen & Queen, 2015; Pavlovskaya, 2016), particularly in the context of complex and multifaceted historical datasets involving uncertainty. This paper conceptually discusses these issues from a design perspective in the context of DH, specifically looking at cartographic design, interaction design and data structure. Subsequently, it briefly reveals how these angles were addressed in an enhanced 2D geographical maps viewer created within the Virtual Interiors project[1] (2018-2022), which displays spatio-temporal historical datasets.

Visualizing data via interactive maps

The prime focus of this paper is visualization via thematic maps, i.e. geographical maps which present *data* as opposed to maps representing *places* (e.g., a reference map). Map visualizations can potentially be used during different stages of the research process (Cairo, 2016; Huurdeman, 2017): at an initial stage (*exploration*), to derive new knowledge (*discovery & interpretation*) and as an end product for disseminating research outcomes (*communication*).

A core issue with maps is that they are an abstraction and thus "not an objective depiction of reality" – the practice of cartography is "as much about removing things as depicting them" (Axis Maps, 2017). Map creators organize and prioritize (Allen & Queen, 2015), thus creating "presences and absences" in the resulting maps (Cosgrove, 1999). This also has large implications for the eventual interpretation of data presented on maps. During the process of presenting data on maps, cartographic design plays a pivotal role, i.e. "the use of graphical techniques to represent geographic information on a map" (ESRI, 2006). *Visual variables*, for instance Bertin (1967)'s retinal variables[2], facilitate understanding the graphical elements which represent data, such as map markers, while *visual hierarchy* involves the ordering between layers in the foreground and background. Careful balancing of these aspects is needed to create understandable and usable map visualizations.

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[1] https://www.virtualinteriorsproject.nl (accessed 03/05/2024)

[2] Bertin (1967) distinguished *selective variables* (quickly isolate group of variables), *ordered variables* (with recognizable sequence), *associative variables* (recognize groups) and *quantitative variables* (estimating numerical differences). These variables can be represented using visual variables involving e.g. position, shape, values, hues, and textures.

Abstract presented at DH Benelux, 04-07 June 2024, Leuven, Belgium. DOI: https://doi.org/10.5281/zenodo.11457262

In this paper, we focus on interactive map visualizations on the web ("web mapping", see e.g. Elliot & Gillies, 2009), which can be used as *tools* themselves in different stages of the research process. This connects to Cairo (2016)'s notion that data visualizations are not just intended to convey predefined messages, but "are often conceived as tools that let people extract their own conclusions from the data"
The interaction between a user and the map tool itself is mediated via the so-called "user interface". The user interface has been characterized as an "in-between device" (Gane & Beer, 2008), for which the "usability" should be optimized (Jacko, 2012). In addition, ideally the functionality of a tool in a Humanities context should allow for "acts of interpretation rather than simply returning selected results from a pre-existing data set" (Drucker, 2013). Thus, besides the cartographic design, also interface and interaction design are of key importance. Taking Geographical Information Systems (GIS)[3] as an example, the "tools for navigation, querying, and feature description convey the impression that we are dealing with static, descriptive information", but not that we are engaging in the "dynamic, often destabilizing" process of interpretation (Johnson, 2015). The question remains, however, if the affordances[4] (Norman, 2013) of current web-based mapping tools, which can be considered a subset of GIS, could actually support this.

Web mapping: issues in cartographic design, interaction design & data structure
To publish map visualizations on the web, various – often iterative – steps need to be taken, depending on the nature of the dataset (see e.g. Fry, 2007). We can group these steps under dataset creation, data wrangling (e.g. cleaning), data enrichment (e.g. "geocoding"), data imports into a web-based tool, and creation of the spatial visualization itself. Standard web-based map visualization tools (e.g. Google Maps, Kepler.gl) allow for relatively straightforward importing and visualization of data with precise geolocations, but lack various aspects essential for handling and visualizing DH data.

A first issue is related to the cartographic design: (historical) data points in a DH context are frequently uncertain (see Li, 2024, forthcoming) or unknown. Often, uncertainty is divided into the *what* (attribute uncertainty); the *where* (positional uncertainty) and the *when* (temporal uncertainty)[5]. In terms of visual representation, there are very few established methods to deal with these aspects in available web-based mapping tools. Moreover, importing data with uncertain or unknown geocoordinates into such tools is often impossible.
A second issue relates to the interaction design of current tools. Web-based maps often provide limited exploration and analysis possibilities. While in many tools search and filtering functionality is available, this usually is only focused on singular data points presented on the map. Searching for and filtering of map points without an assigned location,

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[3] For instance, QGIS or ArcGIS. Computer-based GIS tools include advanced ways to administer (geocoded) map data, to utilize different data layers and to spatially analyze data.
[4] The "affordances" of an object determine how it can be used.
[5] See e.g. MacEachren et al. (2005) and https://www.e-education.psu.edu/geog486/node/693 (accessed 03/05/2024)

aggregated searches (e.g. a map region) and using the underlying metadata[6] within the search is often impossible. The third issue relates to the data structure: included data is frequently not using common identifiers to distinguish its properties, such as Linked Data *URIs*[7]. Therefore, it is not possible to dive deeper into the underlying metadata of map points and to explore *beyond* these points.

Within the Digital Humanities, some web-based tools have emerged for specific purposes, such as spatio-temporal comparisons (DARIAH-DE Geo-browser) and for visualizing spatial networks (Palladio). However, few tools combine explicit uncertainty displays, aggregated searching and Linked Data. In the next section, we discuss a concrete approach for this combination.

Demonstrating a web-based research environment

Within the Virtual Interiors project (2018-2022), research was conducted on cultural production and consumption of the creative industries in the context of 17th Century Amsterdam. Interactive 2D and 3D research environments were constructed within the project[8]. In this paper, we focus on the created 2D maps environment, in which part of the dissertation research by Li (2023) was visualized. The research involved *deep mapping* (see Li, 2023; Earley-Spadoni, 2017) of artists' locations within Amsterdam. Physical locations served as an "anchor for the alignment of historical maps, archival materials, and modern databases like *ECARTICO* and *RKDimages*."[9] A co-design method (Zamenopoulos & Alexiou, 2018) was employed for the creation of a demonstrator for a 2D research environment[10]. The demonstrator was created in iterative steps in a close and frequent interdisciplinary collaboration between the involved art historian (Li, 2023), HCI researcher and expert on digital editions[11]. In this process, prior literature on cartographic and user interface design was taken into account (e.g. MacEachren, 2015; Ahlberg & Shneiderman, 1994; White & Roth, 2009). This was followed by a user evaluation. Next, we discuss the three issues raised in the previous section and how these were addressed in the demonstrator.

First, regarding cartographic design: various uncertainty was involved in the mapping of the physical locations of artists and art dealers (cf. MacEachren, 2015). This involved *positional*

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[6] See e.g. Koller, D., Frischer, B., & Humphreys, G. (2009).

[7] E.g. by using "uniform identifiers" (URIs) and via open standards (e.g. the query language SPARQL (Berners-Lee, 2009)). Linked Data is modeled in a more universal, interconnectable and machine processable way (Antoniou & Van Harmelen, 2008).

[8] The 3D viewer is discussed in detail in Huurdeman & Piccoli (2021) and can be viewed via https://www.virtualinteriorsproject.nl/output (accessed 03/05/2024). The basic user interface (e.g. panels and menus) is shared between the 3D viewer and the 2D viewer discussed in this paper.

[9] https://www.virtualinteriorsproject.nl/centres-of-creativity-in-amsterdam-of-the-dutch-golden-age/ (accessed 03/05/2024)

[10] The demonstrator distinguishes underlying map layers (ATM), historical streetplan layers (Adamlink) and data layers. For preservation and potential reuse, documentation, source code and a demo can be found on GitLab and Zenodo: https://gitlab.com/uvacreate/virtual-interiors/virtual-interiors-2d-research-envi (accessed 03/05/2024)

[11] Specifically, with the researcher (Li, 2023), the author of this paper, and team member Etienne Posthumus at Brill Publishers.

uncertainty (e.g. 'where was the workshop of this artist located exactly?'), *temporal uncertainty* (for example 'when was the artist active at which location?') and *attribute uncertainty* (e.g. 'are we sure these archive documents talk about the same artist?'). Various ways to represent positional uncertainty were discussed and practically tested, in part inspired by previous literature (e.g., via different visual variables). Ultimately, we arrived at the visualization depicted in Figure 1A: using map markers for basic display of artists' locations and using polygon shapes representing the whole area that the artist may have worked in (Figure 1B). The latter appear after selecting an artist, thus explicitly representing the positional uncertainty of the location. Thus, we overcame the limitation of being required to tie data points to a specific geolocation as other tools have. The underlying data often lacked precision with respect to the temporal dimension. Therefore, data is represented using adjustable time range filters (1, 5 or 10-year ranges), rather than only for specific years. While attribute uncertainty is not explicitly visualized on the spatial map itself, it can be inspected via the item details and included linked references (Figure 1C).

Second, the map demonstrator offers dynamic searching and filtering via a side-panel, thus offering 'details-on-demand' (cf. Ahlberg & Shneiderman, 1994; White & Roth, 2009). Underlying data points about painters and art dealers can be searched and inspected via seamlessly linked spatial and list-based views (Figure 2A). The list also displays items *without* a known location, overcoming the issue of requiring geolocations in standard web mapping tools. Filters for each metadata entry allow for making pinpointed aggregated selections, for instance based on year or occupation. In addition, aggregated map points in a certain spatial area can be selected by drawing a rectangle in the map display. For these kinds of aggregated selections, image galleries can be shown, to e.g. compare visual styles of artists in a certain area (Figure 2B). This provides some initial possibilities for the exploration and interpretation of content in the application.

Third, pertaining the data structure, the demonstrator directly uses Linked Data to display data and connect to other sources, based on included identifiers from ECARTICO[12]. Upon selecting a map point, biographical information is retrieved from ECARTICO and displayed in the interface. ECARTICO is also used as a "lynchpin" to connect to other linked data, such as from Wikidata and Adamnet (see also Li, Piccoli & van den Heuvel, 2019; Huurdeman, Piccoli & Van Wissen, 2021). Thus, links to other data sources – e.g. the RKD-page pertaining an artist – can be followed, which allows for further exploration and consultation of in-depth information.

A prototype of the maps interface has been evaluated in a user study (2021) focused on usability (Jacko, 2012), which highlighted the tool's usefulness and potential for deep exploration, but also revealed potential points of improvement regarding cartographic design

[12] ECARTICO (https://ecartico.org/, accessed 03/05/2024) contains structured biographical data concerning people involved in the cultural industries in the Low Countries and is also accessible via a Linked Data endpoint.

and usability, which have been partially addressed. The study further underlined the notion that map visualizations, as abstractions of reality, need to carefully balance visual variables, visual hierarchy, and interaction design.

Conclusion and further research

Within a DH context, this paper discussed a conceptual framework and conceptualized the complexities and opportunities in web mapping through the lens of cartographic design, interaction design, and data structures. The traditional role of geographical maps as abstract representations of reality poses inherent challenges, in particular when visualizing multifaceted historical datasets fraught with uncertainties. While only a starting point, the presented 2D maps research environment exemplifies ways to address these challenges: by visualizing positional and temporal uncertainty, by using dynamic searching and filtering, and via interconnected Linked Data. In future work, the presented (open-source) tool could be extended further, for instance with graphs of distributions and artist networks. This paper and the demonstrator[13] may serve as a basis for further work, with the hope that future interactive web maps can increasingly facilitate interpretation.

Acknowledgements

The author wishes to thank all Virtual Interiors team members, in particular Weixuan Li and Etienne Posthumus, involved in the co-design of the 2D maps demonstrator discussed in this paper.

Figures

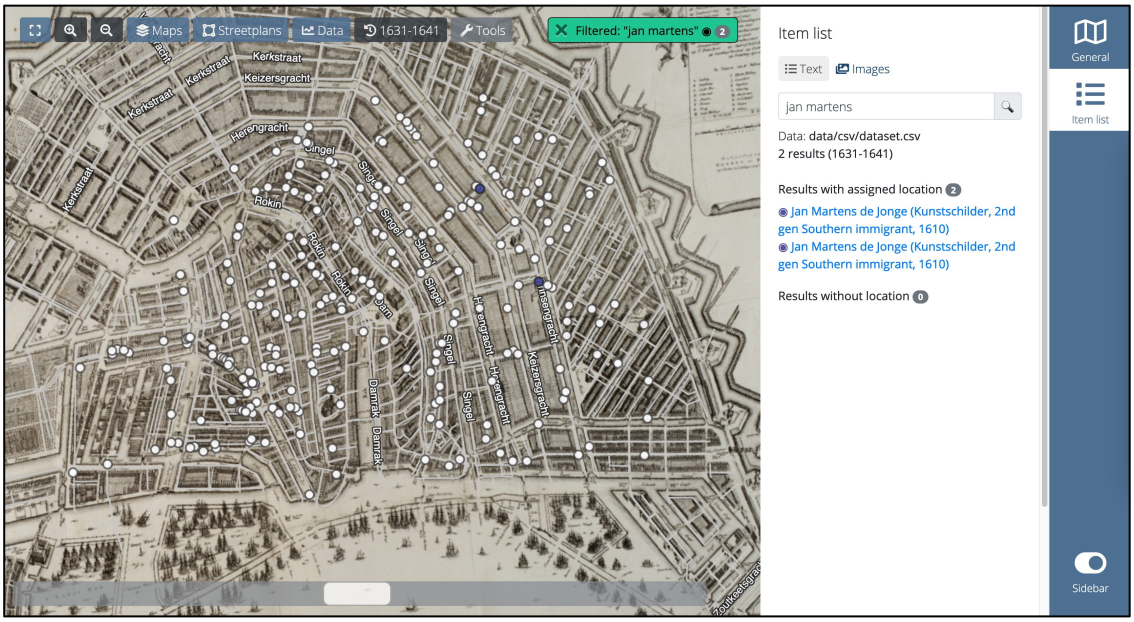

Figure 1A: Virtual Interiors maps demonstrator interface, De Broen map selected, with issued query for the painter "Jan Martens". Two resulting map markers are highlighted on the map and displayed in the sidebar. Using the timeline at the bottom, the displayed time period can be customized.

[13] The demonstrator is available via: https://2d-demo.virtualinteriorsproject.nl/ (accessed 03/05/2024)

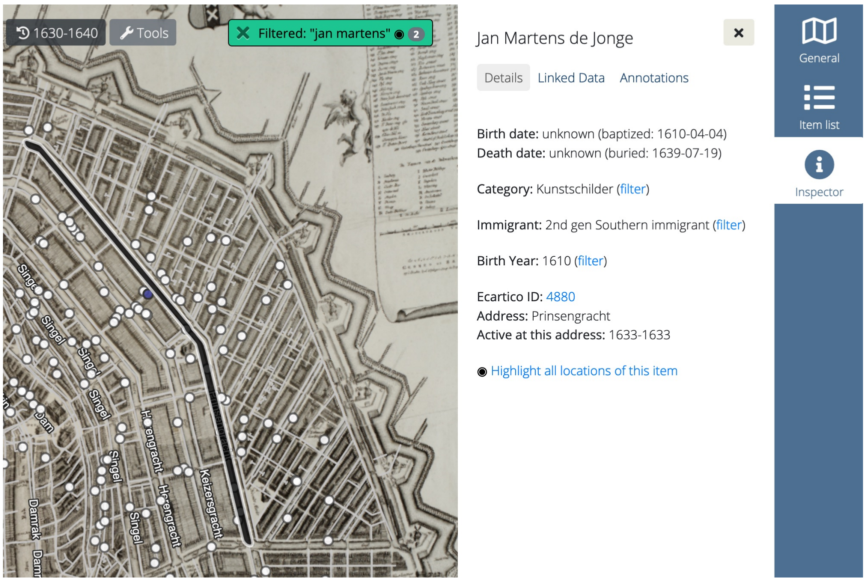

Figure 1B (cropped image). After clicking one of the map markers, the whole potentially uncertain area ("Prinsengracht") of this painter is highlighted. Additional data is automatically retrieved from ECARTICO.

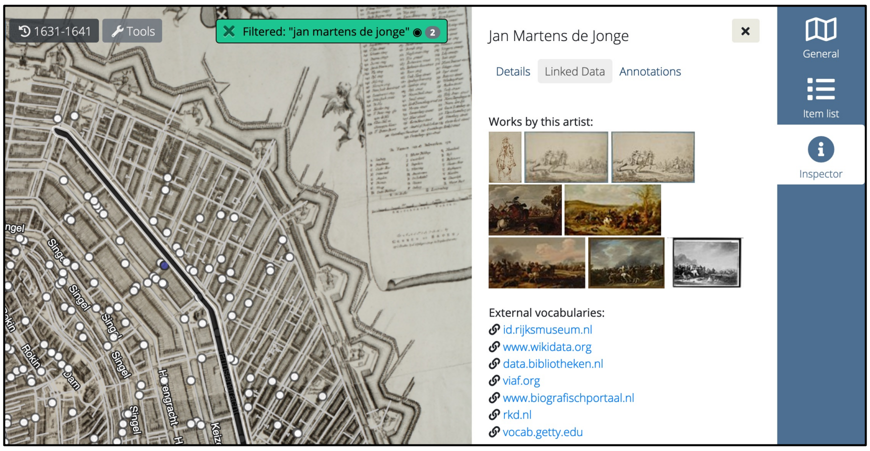

Figure 1C (cropped image): Via the "Linked Data" tab, paintings by this artist and external references can be accessed; via "Annotations", textual annotations can be added.

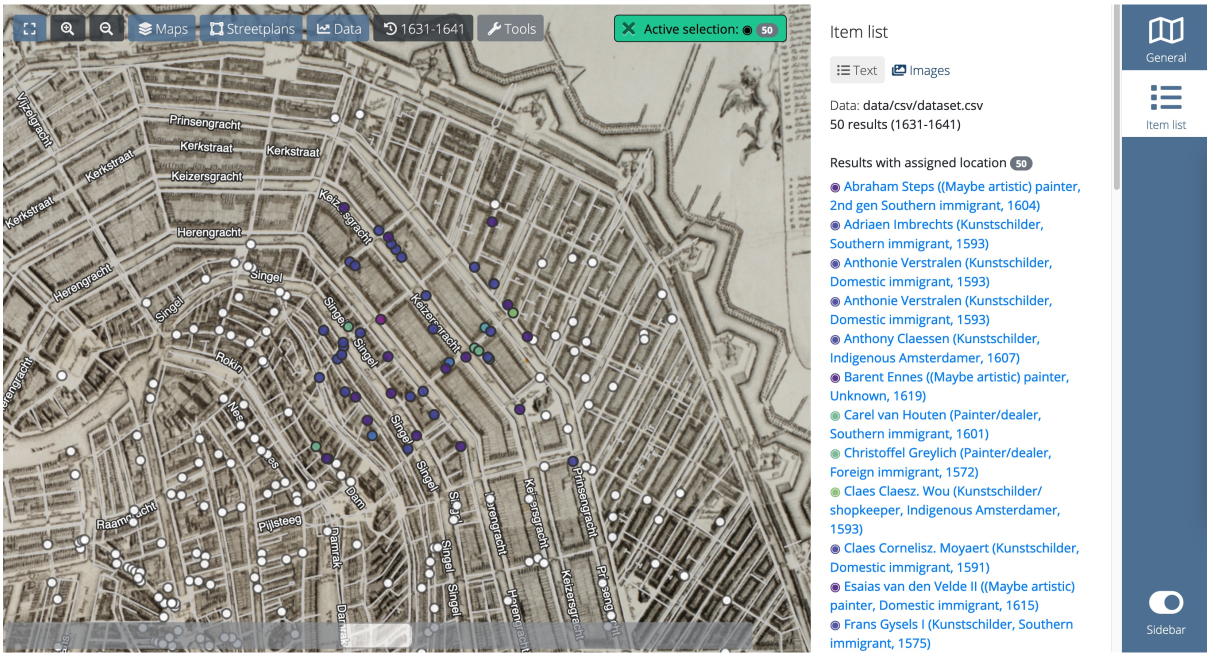

Figure 2A: Selected map region (control-click), with results displayed on the right-hand side.

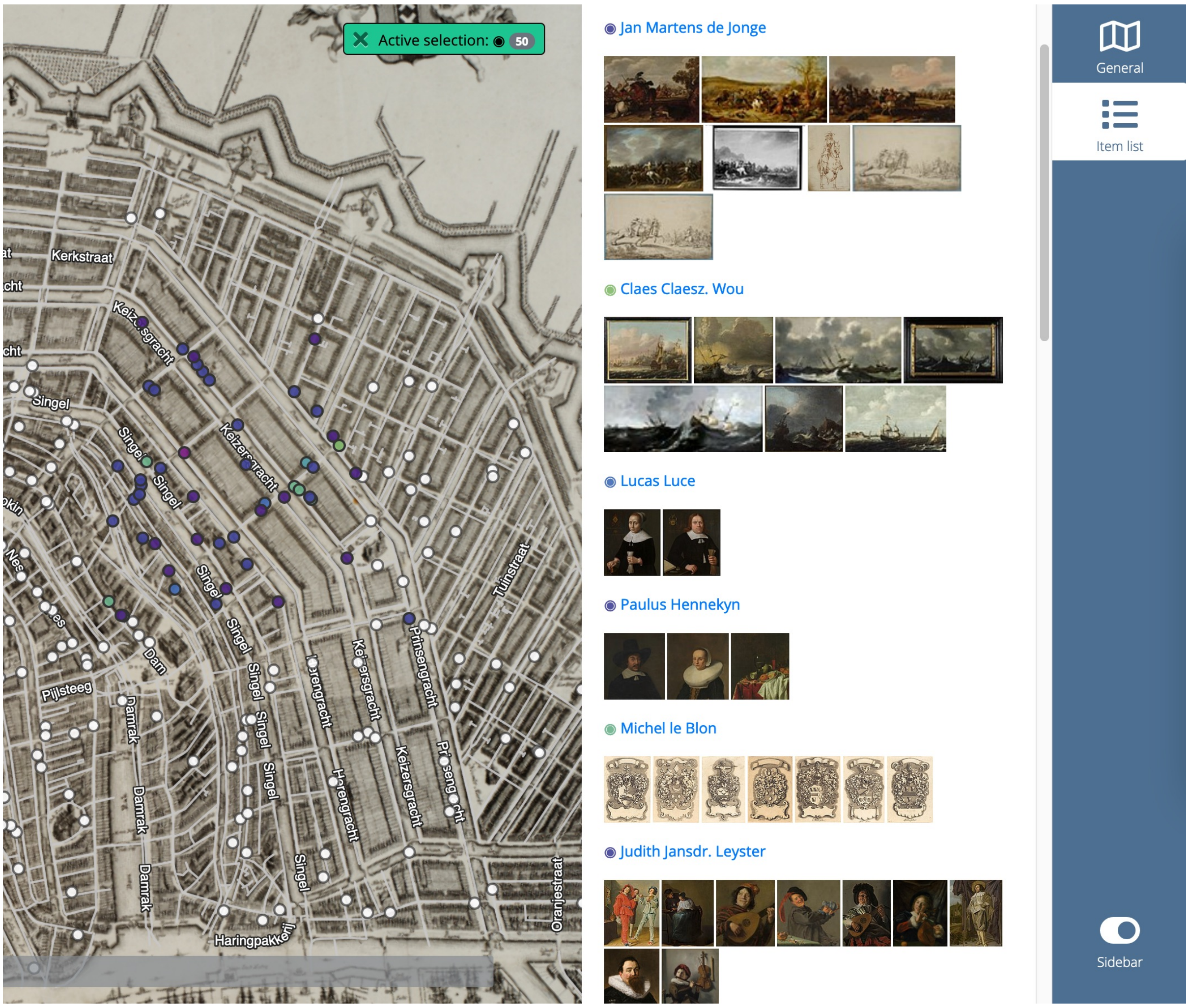

Figure 2B (cropped image): Selected spatial region, images retrieved from Linked Data sources (e.g. Wikidata). A large version of an image can be opened by clicking a thumbnail.

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