Spatial Cognition & Computation
An Interdisciplinary Journal

ISSN: 1387-5868 (Print) 1542-7633 (Online) Journal homepage: http://www.tandfonline.com/loi/hscc20

How does GIScience support spatio-temporal information search in the humanities?

André Bruggmann & Sara I. Fabrikant

To cite this article: André Bruggmann & Sara I. Fabrikant (2016): How does GIScience support spatio-temporal information search in the humanities?, Spatial Cognition & Computation, DOI: 10.1080/13875868.2016.1157881

To link to this article: http://dx.doi.org/10.1080/13875868.2016.1157881

Accepted author version posted online: 02 Mar 2016.
Published online: 02 Mar 2016.

SPATIAL COGNITION & COMPUTATION
http://dx.doi.org/10.1080/13875868.2016.1157881

Taylor & Francis
Taylor & Francis Group

How does GIScience support spatio-temporal information search in the humanities?

André Bruggmann and Sara I. Fabrikant

Department of Geography, University of Zurich, Zurich, Switzerland

ABSTRACT
Recent text digitization efforts make it possible to extract implicit and explicit spatio-temporal information with automated methods. We propose a GIScience approach to information search and access to visually explore digital text archives typically employed in the humanities. We detail how to extract and reorganize spatio-temporal information buried in text documents about Swiss history, based on established GIScience methods, and how to present this information to target users in an empirically evaluated visual analytics interface. Early involvement of users in this user-centered interface design process significantly improved initial design ideas. With this interdisciplinary approach to spatio-temporal information exploration and search, we hope to provide the digital humanities community novel ways to access and explore large text archives containing spatio-temporal information.

KEYWORDS
digital humanities; geovisual analytics; information search

1. Introduction

The amount of information that is digitally available in massive online archives has risen dramatically in recent years. Drivers of this trend are the growing popularity of user-generated content (e.g., Wikipedia) and open data initiatives.

Also contributing to this trend is the large-scale digitization of information (e.g., books, images, and videos) that has not been stored digitally before—it is being pushed intensely by many (state) institutions, organizations, and companies (e.g., Google).

Due to this online availability of multimedia data, scientists with different research foci (e.g., computer science, data mining, information visualization, etc.) have been interested in developing new methods to search, explore, and make sense of this deluge of information.

Particularly interesting and relevant for the humanities, many of these online data archives consist of unstructured or semi-structured text documents (e.g., books) because text documents have been central to the humanities long before digitization. As digital text archives become more easily accessible and contain both explicit and implicit spatial and temporal information, researchers in geographic information science (GIScience) have become aware of these new

CONTACT André Bruggmann andre.bruggmann@geo.uzh.ch Department of Geography, University of Zurich, Winterthurerstrasse 190, 8057 Zurich, Switzerland.

digital data sources for space-time analyses. However, the development of effective and efficient search tools to explore these data sources and to present search results in perceptually salient and cognitively supportive maps to target users (e.g., in the humanities) are still major challenges to be addressed by the communities interested in space-time search (Ballatore, Hegarty, Kuhn, & Parsons, 2015). An ongoing debate by humanities scholars about (web) interfaces and respective interface design issues to access text databases highlights the necessity for knowledge transfer and exchange across disciplinary boundaries to better understand information demands and provide appropriate information search solutions (e.g., Berry, 2012; Drucker, 2011; Kirschenbaum, 2004).

This motivated us to develop a systematic approach, which involves all steps from raw data processing to the development of an interactive tool that would allow humanities experts to interactively search and explore spatio-temporal data, and continuously involving the target users in the interface design process. In doing so, we can answer the research question, *how* the GIScience community can support spatio-temporal search in the humanities. Typical GIScience methods from geographic information retrieval (GIR), spatialization, and geovisual analytics (GeoVA) are thus considered.

We employ a lexicon about the history of Switzerland as a case study because this lexicon represents a typical online text archive produced by humanities scholars and used by humanities experts as well as the general public. This planned exploratory web tool, which will be the final output of our research project, will allow target users to perform spatio-temporal information search tasks based on Shneiderman's (1996) Visual Information-Seeking Mantra: get an overview of the data first, then zoom in and filter, and finally get details on demand.

Following this approach we hope to provide humanities scholars and information seekers the opportunity to generate new hypotheses about and to gain new insights into Swiss history from a GIScience point of view.

The remainder of this article illustrates the steps from raw data processing to the empirical evaluation of a proof-of-concept interface and respective design mockups with target users. An outlook suggests necessary future steps as to develop a fully functional interactive information seeking tool.

2. Background

Our approach covers methods from three different research fields at different stages of our project, as can be seen in Figure 1. Relevant prior work is discussed next.

First, Geographic Information Retrieval (GIR) methods are used to extract information about space and time from the lexicon entries. From a space point of view, Derungs and Purves (2014) present a consistent framework to

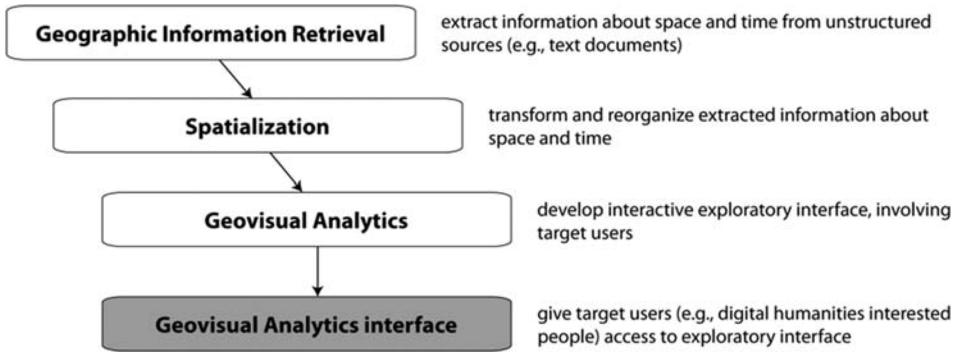

Figure 1. The three main research fields that inspired and lays the theoretical foundation for this research project and a geovisual analytics interface as a targeted outcome.

automatically detect, disambiguate (e.g., London, UK vs. London, Ontario, Canada), and index toponyms (e.g., a city) from unstructured or semi-structured text using a gazetteer (i.e., list of potential toponyms). How to automatically retrieve and standardize temporal information (e.g., date, time, duration, etc.) from text documents has been, for example, addressed by Strötgen and Gertz (2013) and implemented in Heideltime, an open source temporal tagger for text documents in various languages.

Having extracted these data about space and time, the visualization community has suggested solutions that visually support the exploration and the generation of hypotheses by transforming and reorganizing such extracted information. In this context, the spatialization framework seems to be highly relevant as it provides a systematic approach to transform high-dimensional numerical and non-numerical data into lower-dimensional, spatial visualizations using spatial metaphors (Skupin & Fabrikant, 2007). Kuhn (1996) develops a theoretical basis for the spatialization of user interfaces, and provides guidelines how to apply it. Following these guidelines, network visualizations represent one possible technique to spatialize multivariate data. In a network visualization, input objects, conceptualized as nodes, are placed close to one another, and are connected with an edge (i.e., a line) if they share similar attributes (Fabrikant, Montello, Ruocco, & Middleton, 2004).

Finally, geovisual analytics (GeoVA) methods are considered for including the spatialized displays in an interactive and exploratory interface, involving target users early on in the interface development process, as depicted in Figure 1. One key aspect of GeoVA (Andrienko et al., 2010) is dealing with massive spatio-temporal data sets, as illustrated in Luo, Yin, Di, Hardisty, and MacEachren (2014). These authors explore complex geo-social relationships in an international trade network using traditional network visualization techniques, and additionally present them to users in a dynamic and interactive GeoSocialApp. In a similar vein, Roth, Ross, and MacEachren (2015) describe a user-centered design process for an interactive and web-based mapping application supporting visual analytics of criminal activity in space and time. They include their target users throughout the design and development process of their GeoVISTA CrimeViz tool by, for example, a needs assessment and an expert-based think aloud study.

In the following sections we illustrate how we combined methods from these three research fields to develop an exploratory GeoVA interface, involving the target users in the design process (e.g., persons interested in digital humanities).

3. Methods

In this section we present the data source employed in our research project and then illustrate our three-step approach from the raw data to the development of an exploratory GeoVA interface, as illustrated in Figure 1.

3.1. Data

We chose the Historical Dictionary of Switzerland (HDS) as a prototypical data source for our approach (HDS, 2015). This choice is based on several reasons. The HDS is a typical example of a multilingual (i.e., German, French, Italian) online digital text archive in the humanities. It contains 36,188 articles about the history of Switzerland, written by historians, and categorized in thematic contributions (e.g., events, institutions, political parties, and activities), geographical entities (e.g., municipalities), biographies, and articles about important families in Swiss history. The semi-structured articles contain much explicit and implicit spatial and temporal information. However, so far this information has neither been retrieved nor systematically analyzed. Furthermore, in the current online version of the HLS, only limited querying options (i.e., title or full text query) are available, and spatial and temporal information search possibilities are not available. Up to this point, only the German version of the HDS has been considered in our research project.

3.2. From GIR to spatialization

To retrieve spatial and temporal information, we employ established GIR methods to our raw HDS data, as presented in own prior work (Bruggmann & Fabrikant, 2014a, 2014b). In the next step, we depict the retrieved information in a spatialized network display in a perceptually salient and cognitively supportive manner as to facilitate information search. These two steps are illustrated schematically in Figure 2.

In the first step, we applied a slightly adapted version of the method described in Derungs and Purves (2014) to retrieve toponyms (e.g., cities,

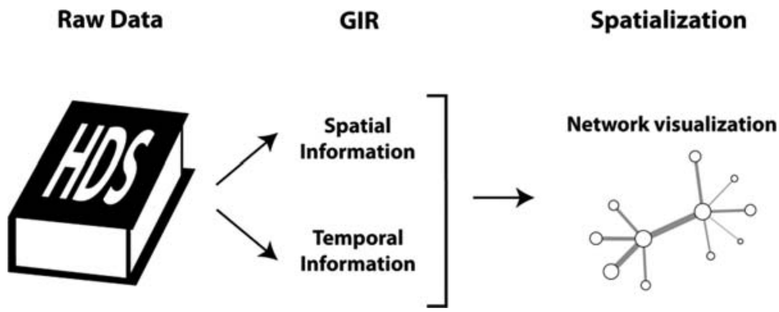

Figure 2. Two-step approach to get from raw input data to spatial and temporal information and finally to a spatialized display.

villages, rivers, or mountains) from the dictionary. The GIR results used in this article differ substantially from previous publications (e.g., Bruggmann & Fabrikant, 2014b), as we employ a more recent version of the HLS, and we eliminated limiting factors in the code, which hindered the full potential of the retrieval process. As a result of these changes, we were able to extract 355,124 toponyms, compared to 169,094 in Bruggmann and Fabrikant (2014b), from the 36,188 articles, of which 16,808 toponyms are unique. We also retrieved dates (e.g., 06/07/1905), periods of time (e.g., 20th century), and other temporal information from the HDS articles by employing a newer version of *Heideltime* (Strötgen & Gertz, 2013). In total, 510,480 temporal expressions were found, compared to 510,357 in Bruggmann and Fabrikant (2014b).

As illustrated in Figure 2, the next step is to depict this multivariate information in spatialized displays because we wish to support information search by perceptually salient and cognitively supportive design principles (Fabrikant & Buttenfield, 2001). We decided to use network visualizations to depict spatio-temporal information because they visually emphasize the inherent connectedness and elicited hierarchical structure of places. This choice was supported by wishes of our target users in the focus group meeting. Further findings of the focus group approach are reported in Section 4.1.

Regarding the temporal unit of analysis, we selected centuries, and thus aggregated the extracted temporal expressions to centuries (e.g., the date 06/07/1905 is a member of the 20th century). Next, we assigned each article a century weight, according to the frequency of temporal expressions in the article (e.g., article A: 20th century 0.3, 19th century 0.6, 18th century 0.1). Inspired by Hecht and Raubal (2008), we assumed a (semantic) relationship between two toponyms if they co-occurred in the same articles.

To combine this information about co-occurrences and about the centuries, we calculated the total strength of toponym relationships in a specific century by summing up the temporally weighted co-occurrence score of two toponyms that co-occur in the same article. The more often that two toponyms occur together in articles with a high percentage of temporal expressions categorized

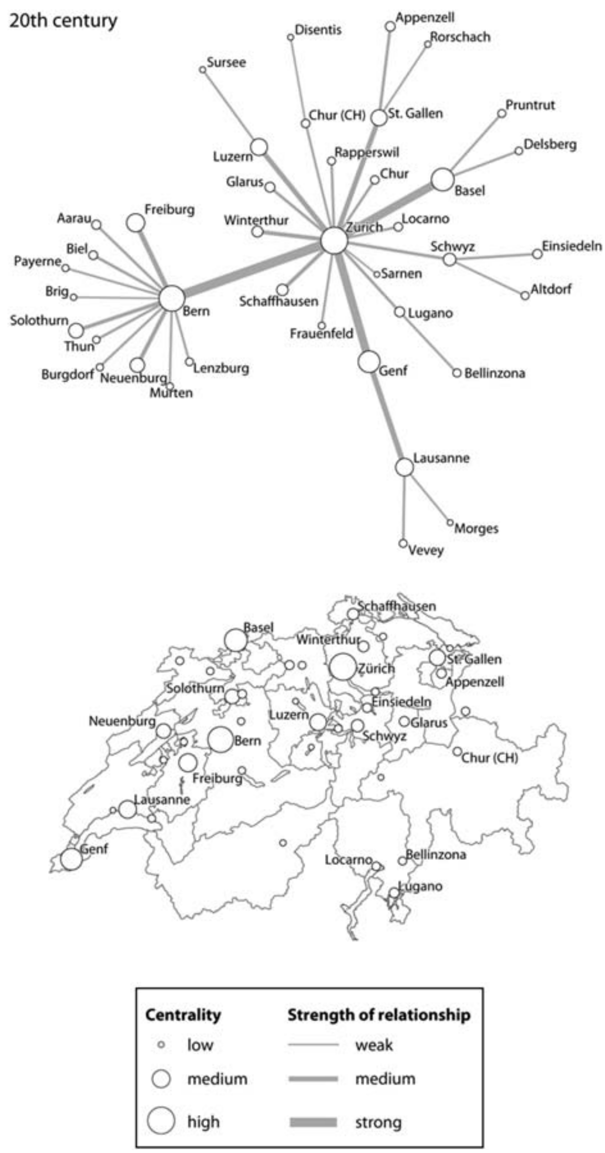

Figure 3. Spatialized network visualization with toponym relationships in the 20^{th} century and corresponding map.

as 20^{th} century, the stronger their relationships in the 20^{th} century. As an example, Figure 3 illustrates a network visualization with the 40 most frequent toponyms in the HLS. The stronger a toponym relationship, the closer two toponyms are placed together and the larger the edge that connects them. The size of the toponyms corresponds with their centrality (i.e., the sum of weighted relationships to all other toponyms in the network). At the bottom of Figure 3, the same information is depicted in a map of Switzerland. A detailed description of the results can be found in Bruggmann and Fabrikant (2014b).

3.3. From spatialization to geovisual analytics

To present our spatialized displays to target users, we developed an interactive GeoVA interface. Inspired by Roth et al. (2015) and following classical user-centered design principles (e.g., Lewis & Rieman, 1993) we decided for an iterative graphical user interface design and evaluation approach, involving the three keys to interface success: a focus on the *user* (i.e., domain expertise), *utility* (i.e., the usefulness of an interface for tasks completion), and *usability* (i.e., the ease of use of the interface for task completion). As mentioned earlier perceptual saliency and cognitive adequacy were important to us thus we adapted the well-studied and tested Visual Information-Seeking Mantra (Shneiderman, 1996) that allows users to gain an overview of the data first, then provides mechanisms to zoom into the data space and filter the data first before getting the details through traditional search (Fabrikant, 2000). In Figure 4, the first part of the design process in Roth et al. (2015) is illustrated (middle column) and visually compared to our approach (right column). The area in grey indicates a substantial difference compared to Roth et al. (2015), as at this stage, instead of the user, the designer is involved. This is inspired by Lewis and Rieman (1993) and are explained later.

We first conducted a focus group following Rubin and Chisnell (2008). An important prerequisite for the focus group method is a clear definition of the target group. In our project, we defined the target group as follows: historians who are interested in new media types and methods to explore history, people who are interested in digital humanities, and those who are interested in interactive interfaces to explore the humanities in general. We invited five representative people who all have an educational background in history, two with a minor in geography. They all share an interest in new media and tools to explore history.

During the first 30 minutes of the focus group meeting, a presentation was held by the moderator who presented the project aims and the goal of the focus group. This was followed by a 60-minute discussion that was audio-taped. The moderator raised questions about the initial ideas of the planned interface design and promoted interaction among participants to discover their needs. As a further output of the meeting, a task list was elaborated. After the meeting, the task list was revised and used as an input to draw paper mockup ideas of the exploratory GeoVA interface.

Next, we conducted a cognitive walkthrough, as illustrated in Figure 4. In a cognitive walkthrough, the designer simulates thoughts and decisions of target users in different interface use scenarios to identify and resolve possible design issues (e.g., poor choices of naming interface menus) before presenting interface mockups to real users. The walkthrough scenarios consist of realistic tasks, and are performed with the interface mockups. For each of the tasks, a correct action sequence (e.g., clicking on a dropdown menu, choosing a particular option, etc.) is defined up front, and for each of the actions a sketch

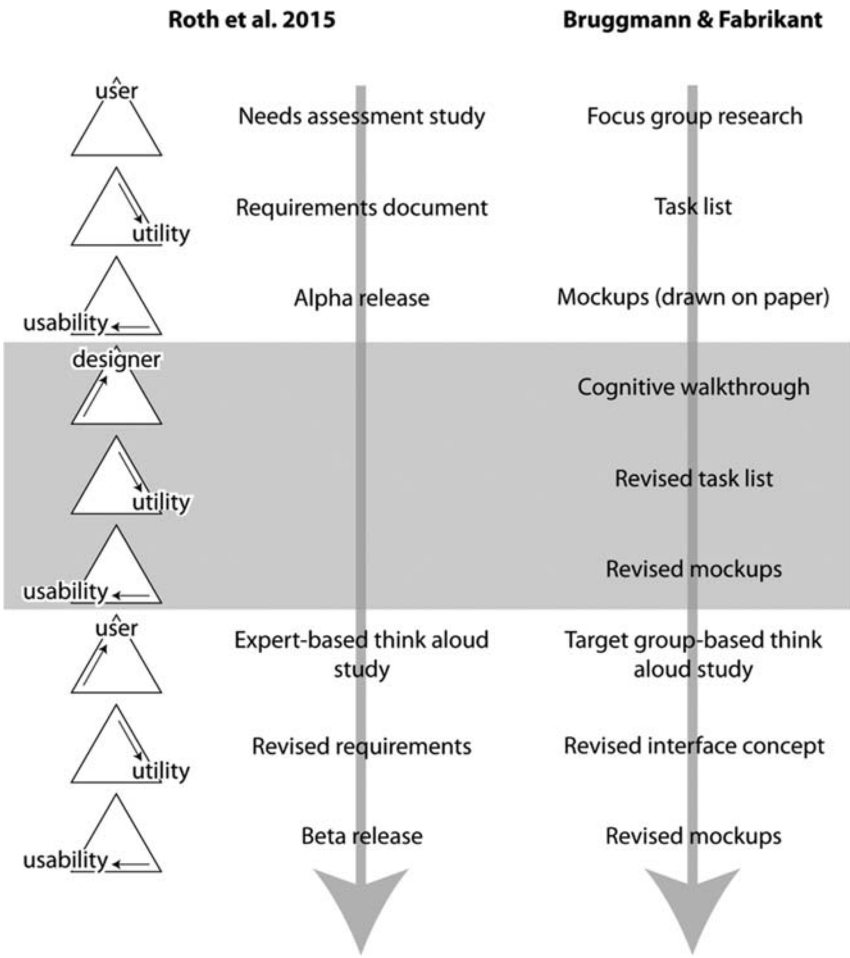

Figure 4. User- and task-centered interface design process, after Roth et al. (2015). In the left column, the iterative process with user / designer, utility, and usability is illustrated. The middle column shows the steps as suggested by Roth et al. (2015), and in the column on the right, we present our own approach.

showing how the interface would look like before execution of this action is developed. In the analysis phase, the designer goes through each task, and tries to tell a credible story if and how the target users might perform the action. These success or failure stories help the designer to revise the task list and the mockups (Wharton, Rieman, Lewis, & Polson, 1994).

In the next step, we conducted a think aloud study, as depicted in Figure 4. We decided to follow the approach of Lewis and Rieman (1993), and work with target users instead of design experts, in contrast to Roth et al. (2015). Nevertheless, we included participants that also have some experience with interactive interfaces, as we hoped that they would provide specific feedback on possible interface design issues. We selected three people having some experience with the design of interactive web interfaces, an educational background in geography, and an interest in Swiss history. Two additional participants are historians, while one of them has little and the other had some experience with interactive web interfaces. The chosen number of participants ($n = 5$) follows Nielsen's (1994) suggestion to plan for three to five participants in a think aloud study. Participants worked in individual sessions that lasted about 60 minutes. They were first instructed about the aim of the study, and given basic information about the project in written documentation. During the videotaped portion of the study, participants had to first read the task, then study the interface mockup and explain what actions they would perform to solve the task, give reasons for their decisions, and comment on potential problems they might face. Depending on the users' decisions, the subsequent mockup state was presented. This was repeated until the users finished a given task. Figure 5 schematically illustrates the experimental setup with the positions of the participant and the moderator, the location of the video camera tripod, and the videotaped area in which the hand-drawn mockups were presented to the users.

The moderator did not respond to questions during the evaluation, and did not provide help to complete a task. Only if users were completely lost, was help provided. The moderator kept notes during the think aloud. Finally, participants were thanked for participation and given a voucher. Videotapes of the think aloud sessions were studied to identify common interface issues and to obtain insights on ways to improve the design. This was done by comparing the anticipated action sequences defined in the cognitive walkthrough with the sequence of actions that users performed.

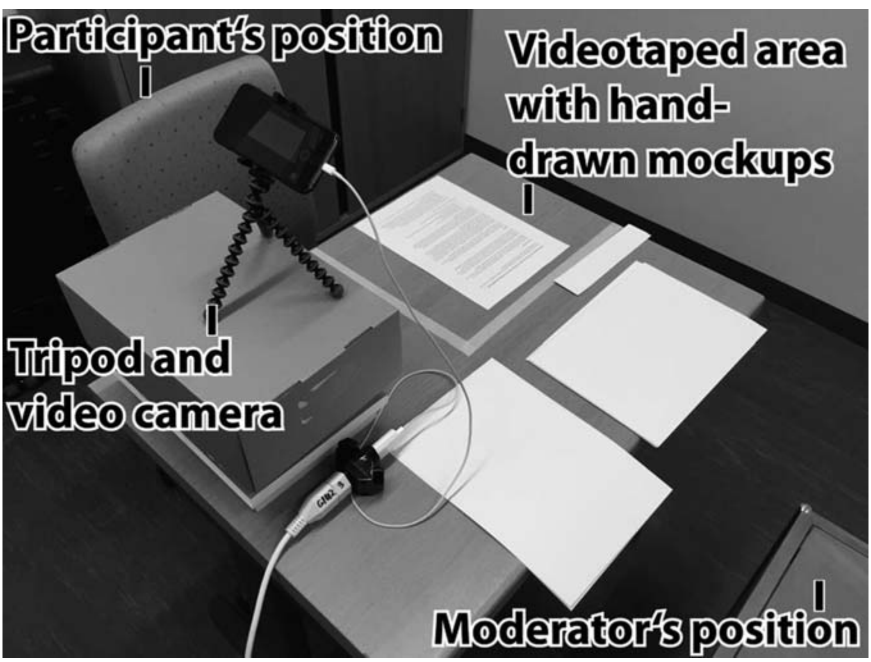

Figure 5. Experimental setup of the think aloud study.

Issues were rated by the designer according to level of importance and difficulty in fixing them, and the benefits gained from the repair. Importance was judged based on potential costs of the issue to users (e.g., in time, aggravation) and the likely proportion of users who would experience similar trouble. Issues that are highly important and easy to fix are more relevant to be fixed than issues that are not as important and very difficult to fix. After completing the tasks, participants were asked to comment on the interface design and on specific situations (e.g., an instance they were completely lost) during the think aloud in a debriefing session.

4. Results

4.1. Focus group research

We first categorized the output collected in the focus group meeting by asking participants about their information needs and search tasks when interacting with a dynamic interface allowing access to the HLS. We identified four main requirements: *interactivity*, *transparency*, *knowledge gain*, and *visualization*.

Regarding *interactivity*, participants stated that they would be interested in inspecting spatio-temporal relationships at different spatial and temporal scales. Further, they agreed on the importance to include thematic information in the visualizations as well. This was the reason for us to consider not only network visualizations, as initially planned, but also self-organizing maps. Due to space constraints self-organizing maps are not further discussed in this article. Interested readers are referred to Bruggmann and Fabrikant (2012). Furthermore, for some participants, access to source information (i.e., the raw data source) is critical. Hence, how the data was processed, and how the data is visualized in the web interface, which we categorized as *transparency*, is important. In addition, *gaining new knowledge* (e.g., to find unexpected relationships) and specific *visualization* techniques to support spatio-temporal and thematic tasks (e.g., support network visualizations with maps) were mentioned. In response to these findings, a prototypical six-item task list was created and is illustrated in a simplified and generic form in Table 1.

In the first column of Table 1, the GeoVA tasks are presented, and in the second column, respective graphical user interface design implications are listed. The participants' requirement for analyzing spatio-temporal relationships at different spatial and temporal scales is considered in Tasks 1 to 4. Because target users suggested to also include thematic information, Tasks 3, 5, and 6 are dealing either with the article categories (i.e., Task 3) or with the thematic information about article-to-article similarities (i.e., Tasks 5 and 6), which could be represented in a self-organizing map (Bruggmann & Fabrikant, 2012). The need to gain new insights (i.e., *knowledge gain*) is potentially given by all the tasks, as they all support exploratory information seeking.

Table 1. Task list and display design implications.

Task	Design implications
1. Compare the strength of two toponym relationships at a certain spatial / temporal scale	Network visualization as shown in Figure 3
2. Identify the strongest spatial relationships of a toponym at a certain spatial / temporal scale	Network visualization with an option to show strongest relationships of a toponym
3. Compare the strength of two toponym relationships regarding a specific article category at a certain spatial / temporal scale	Network visualization with an option to analyze toponym relationships according to article categories
4. Compare the community membership of a toponym in two different centuries	Depictions of different temporal network states next to one another
5. Identify articles about a specific topic and thematically similar articles about a specific topic	Visualization of articles in a self-organizing map
6. Identify toponyms that are most relevant to a specific topic	Visualizations of toponyms in a self-organizing map

The remaining two points (i.e., *transparency* and *interactivity*) will be discussed later. Task 4 deals with community membership, which is not covered in this article, but we refer interested readers to Bruggmann and Fabrikant (2014b).

4.2. Cognitive walkthrough

In the following, we focus only on Task 2 to illustrate the results of the cognitive walkthrough in a representative example. As indicated in Table 1, the idea of Task 2 is to identify the strongest spatial relationships of a toponym at a certain spatial and temporal scale which was requested by our focus group participants. For the cognitive walkthrough we developed a task to find the toponym "Basel" on the spatial scale "Switzerland," and on the temporal scale "19th century." Figure 6 illustrates a hand-drawn mockup of Task 2. As we were dealing with

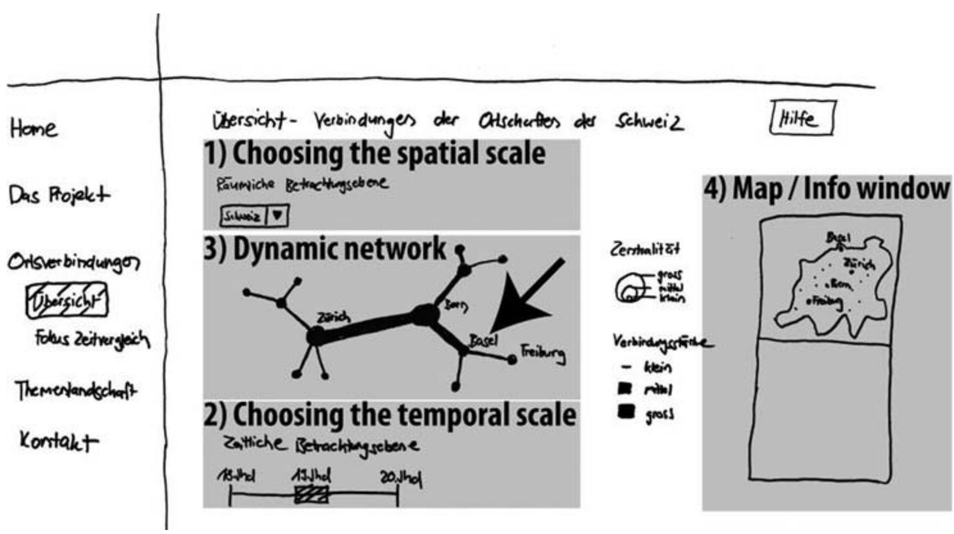

Figure 6. Mockup of the dynamic network visualization for Task 2. Parts of the interface that are important for this task are highlighted in gray.

the history of Switzerland, and we worked with the German version of the HLS, we chose German as the interface language.

On the left in Figure 6, the menu for quick web site navigation is depicted. On the right, the interactive network is visualized. Assuming that the spatial and the temporal scale (numbers 1 and 2 in Figure 6) are by default set to "Switzerland," respectively "19th century," the defined correct action would be to click on "Basel" (number 3 in Figure 6, black arrow is pointing to "Basel"). Were the user to do so, in the map (number 4 in Figure 6) the five strongest relationships would be depicted as edges between the respective toponyms, and the values for the strength of the relationships would be listed in the empty info window below the map. Translated to Shneiderman's (1996) Visual Information-Seeking Mantra this means that users need to identify "Basel" first (i.e., get overview), check that the correct spatial and temporal scale are selected (i.e., then filter), and then click on "Basel" to get additional information (i.e., details on demand). Table 2 illustrates an excerpt of the cognitive walkthrough.

Table 2 illustrates a typical failure story as the user expects a mouseover instead of having to click on a toponym and shows that clicking on "Basel" on the map would be possible. Consequently, the respective functionalities of the interface are adapted.

Across all tasks, we discovered that some interaction elements were inadequate (e.g., clicking vs. mouseover) and some task descriptions were not clear enough (e.g., user gets lost if a menu title is labeled inadequately). With these findings, we were able to revise the task list and the mockups to proceed with the think aloud study.

4.3. Think aloud study

As in the previous section, we now illustrate examples from the results of the think aloud study by focusing on Task 2. Issues, the importance / difficulty rating of these issues, and an answer to the question whether the issue will be fixed are summarized in Table 3.

Table 3 lists two typical and representative problems for all tasks. An issue was that some users did not pay attention to the selected spatial or temporal

Table 2. Cognitive walkthrough for Task 2.

Action	Success or failure?	Story
Clicking on "Basel" in the network	Failure	The user tries to do a mouseover instead of clicking on "Basel," as this is more intuitive. However, the user does not get any feedback from the system while doing the mouseover. The user tries to click on "Basel" in the map instead of clicking on Basel in the network visualization, as this would be more intuitive. However, the user does not get any feedback from the system.

Table 3. Issues, ideas and importance/difficulty rating related to Task 2 to improve the interface concept.

Issue	Importance / Difficulty	Fix?
Users do not realize that they chose the wrong spatial or temporal scale.	High importance, medium difficulty	The interaction elements regarding the spatial and temporal scale will be positioned above the network to be more clearly visible.
The network visualization has no zooming function to access multiple spatial hierarchies of the network.	Low importance, high difficulty	No, not of immediate importance, but probably in a further release.

scale. One user mentioned in the debriefing session that the solution to this problem could be to place both interaction elements for choosing the spatial and temporal scale above the network. Further, some users remarked that it would be a nice feature if they could zoom while interacting with the network visualization to access multiple spatial hierarchies of the network. The first issue will be fixed, the second issue will not be considered for implementing the prototype, as we judged it as being of low importance and highly difficult to be fixed.

Similar issues and ideas resulted from the other tasks. The main issue was that users did not employ the interaction elements as predicted. Moreover, some users suggested further functionalities in the user interface (e.g., when clicking on a toponym in the network, the network should be arranged around the selected toponym).

According to the obtained results, the interface concept and mockups were revised. In Figure 7, the revised mockup of Figure 6 is presented. All the interface elements have the same functionality and are arranged identically

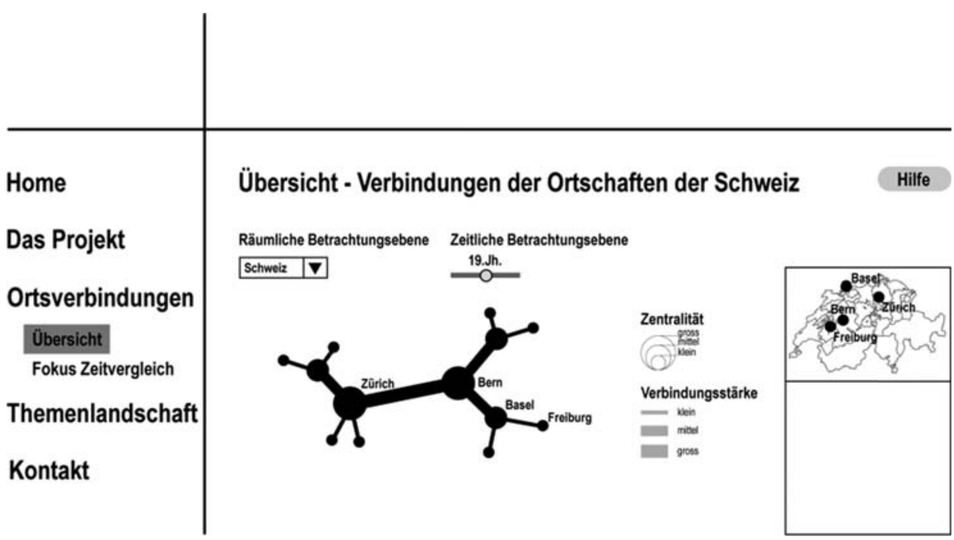

Figure 7. Revised mockup of Figure 6.

to Figure 6, which is why they are not explained again here. However, the bar to choose the temporal scale has been moved up as a result of the think aloud study.

5. Discussion and conclusions

In this article, we provided an answer to the research question stated in the beginning by presenting spatial and temporal information buried in huge digital text archives in an interactive graphical user interface to users interested in exploring the humanities from a GIScience point of view.

As suggested in the GIScience literature (i.e., Roth et al., 2015) and by humanities scholars (i.e., Kirschenbaum, 2004), the involvement of target users at a very early stage of the interface design process proved to be critical for developing a useful and usable user interface for spatio-temporal search. The focus group allowed us to get to know the users, their needs, and ideas for the studied spatial search tasks. We even received input on desired visualization techniques (e.g., combining networks interactively with maps), and on issues such as the importance of transparency, which seem to be highly relevant for our specific target group. In general, the focus group confirmed the strong interest of our target users in the idea of exploring text data in the humanities from a spatio-temporal and thematic point of view, and convinced us to include other spatialized display types beyond network visualizations (i.e., self-organizing maps), to allow for exploring thematic data in more detail. In contrast, coming up with a task list during the focus group session proved to be difficult, mainly due to time constraints. Therefore, substantial revision and reformulation of tasks was necessary subsequent to the meeting. Following Lewis and Rieman (1993), we did the cognitive walkthrough study next. This proved to be very beneficial, as we were able to solve many minor design problems (e.g., wrong labeling of menus) before presenting the interface mockups to real users. Otherwise, the user's attention could have been focused on these minor issues, or worse, the user could have been lost early during the think aloud study (e.g., not finding the correct menu). However, this method also has shortcomings: simulate potential users' thoughts and decisions turned out to be difficult, especially if target users do not have the same background as the designer (i.e., humanities). This fact strongly supports the early involvement of users in systematic design evaluations. The think aloud study was beneficial for us, as we not only identified interaction issues, but additionally obtained useful input from target users regarding the extension of functionality.

Furthermore, the results show how different parts of an interface concept might work together, and if this interplay is understood well by the target users. Regarding this point, the fact that many users had problems with some interaction elements must be highlighted. These users stated in the debriefing session that if the interface had been implemented and presented digitally, this would not have happened. This points to a limitation due to the use of hand-drawn mockups. However, as we were aware of this limitation, we invited people for the think aloud study that are not only target users, but are not completely unfamiliar with interactive web interfaces. In contrast, working with paper mockups has benefits: we saw that participants come up with many good ideas on new functionality that could be a direct consequence of using hand-drawn sketches. This is because users might have had the impression that the sketches are incomplete and less definite than a fully implemented tool, and therefore have the impression that changes in the interface concept are still easily possible at this stage.

The presented approach supports the spatial (and temporal) search communities in finding perceptually salient and cognitively supportive visual representations of search results for target users. This is one of the elaborated optimization goals identified for future research by Ballatore et al. (2015) as result of the Spatial Search Specialist Meeting 2014 in Santa Barbara. Furthermore, the interactive character of the spatialized interface enables an information seeker to visually explore the re-structured spatio-temporal information, as to generate new research hypotheses for further investigations. Moreover, various existing GIScience methods are combined in novel ways, compared to previous related work in GIScience, also capitalizing on co-occurrence and network visualization algorithms (e.g., Luo et al., 2014). The application of these methods to text data, typically employed in the humanities, is a further transdisciplinary contribution to the evolving spatial (and temporal) search challenges (Ballatore et al., 2015).

Furthermore, our approach contributes to the ongoing debates in the digital humanities about the development of usable (web) interfaces, and respective interface design issues that need to be solved (e.g., Drucker, 2011). We illustrate this with a sound methodological approach based on solid GIScience theory from raw data processing to the evaluation and development of an interactive spatialized web interface. Involving target users early on in the interface design process, proves to be critical to better understanding their needs and to receive direct input on design issues and possible functionality extensions.

Furthermore, Shneiderman's (1996) well-known Visual Information-Seeking Mantra provides a systematic framework for the digital humanities community to gain new insights into large text archives by means of computational methods (Berry, 2012; Fabrikant, 2000). Due to the positive feedback of the study participants regarding the novel spatialized displays, promoting the spatialization framework (i.e., Kuhn, 1996) to the digital humanities might be a further implication. Our findings illustrate that target users have a strong interest in visually accessing and exploring text documents using spatial, temporal, and thematic information in interactive graphical user interfaces, which might imply that in the context of the humanities, a geographical rather than a purely spatial approach to information search might be more desirable (Grossner, 2014).

6. Outlook

We will now implement a prototype based on target user feedback in a next step. As we know how the web interface should appear and which functionalities should be included, we are now evaluating different technologies for the implementation (e.g., D3.js, Leaflet, etc.). The prototype development will be again guided by the iterative interface design process, as suggested by Lewis and Rieman (1993) and Roth et al. (2015). In the context of our project, the assessment of analytical products derived not only by digital information seekers broadly interested in the humanities, but also GIS practitioners interested in spatializing non-geographical data sets, which resulted in hypotheses generated by interacting with an interface, knowledge gained while using the interface, and making decisions based on interacting with the interface proved to be a critical evaluation method (Roth et al., 2015). The resultant empirically evaluated implementation should then serve as a useful alternative to the existing online version of the HLS, including the presented spatio-temporal and thematic searching and browsing capabilities to access, search, and explore Swiss history from a GIScience point of view.

Acknowledgments

We would like to thank Curdin Derungs, Jannik Strötgen, and Julian Zell, who specifically helped us to implement the GIR portions of this research. We are also grateful to Katja Hürlimann, Ross. S. Purves, and Damien Palacio for their continued, invaluable feedback on this project.

References

Andrienko, G., Andrienko, N., Demsar, U., Dransch, D., Dykes, J., Fabrikant, S. I., Jern, M., Kraak, M.-J., Schumann, H., & Tominski, C. (2010). Space, time and visual analytics. *International Journal of Geographical Information Science*, *24*(10), 1577–1600.

Ballatore, A., Hegarty, M., Kuhn, W., & Parsons, E. (2015). Spatial Search, Final Report. *Specialist Meeting Position Papers and Reports*. Retrieved from https://escholarship.org/uc/item/33t8h2nw

Berry, D. M. (2012). Introduction: Understanding the digital humanities. In D. M. Berry (Ed.), *Understanding Digital Humanities* (pp. 1–20). Basingstoke, Hampshire, UK: Palgrave Macmillan.

Bruggmann, A., & Fabrikant, S. I. (2012). *Cartograms of self-organizing maps to explore user-generated content*. Paper presented at the ICC 2012 Conference, Dresden, Germany.

Bruggmann, A., & Fabrikant, S. I. (2014a). *How to visualize the geography of Swiss history*. Paper presented at the AGILE 2014 Conference, Castellón, Spain.

Bruggmann, A., & Fabrikant, S. I. (2014b). *Spatializing time in a history text corpus*. Paper presented at the GIScience 2014: Eighth International Conference on Geographic Information Science, Vienna, Austria.

Derungs, C., & Purves, R. S. (2014). From text to landscape: locating, identifying and mapping the use of landscape features in a Swiss Alpine corpus. *International Journal of Geographical Information Science*, *28*(6), 1272–1293. doi:10.1080/13658816.2013.772184

Drucker, J. (2011). Humanities Approaches to Interface Theory. *Culture Machine*. 12. Retrieved from http://www.culturemachine.net/index.php/cm/article/view/434

Fabrikant, S. I. (2000). Spatialized Browsing in Large Data Archives. *Transactions in GIS*, *4*(1), 65–78.

Fabrikant, S. I., & Buttenfield, B. P. (2001). Formalizing Semantic Spaces for Information Access. *Annals of the Association of American Geographers*, *91*, 263–280.

Fabrikant, S. I., Montello, D. R., Ruocco, M., & Middleton, R. S. (2004). The Distance-Similarity Metaphor in Network-Display Spatializations. *Cartography and Geographic Information Science*, *31*(4), 237–252.

Grossner, K. (2014). *Geographic Search*. Paper presented at the Specialist Meeting - Spatial Search, Santa Barbara, CA, USA.

Historical Dictionary of Switzerland (HDS). (2015). Historical Dictionary of Switzerland. Retrieved from http://www.hls-dhs-dss.ch/

Hecht, B., & Raubal, M. (2008). *GeoSR. Geographically explore semantic relations in world knowledge*. Paper presented at the International Conference on Geographic Information Science (AGILE), Girona.

Kirschenbaum, M. G. (2004). "So the Colors Cover the Wires": Interface, Aesthetics, and Usability. In S. Schreibman, R. Siemens, & J. Unsworth (Eds.), *A Companion to Digital Humanities* (pp. 523–542). Oxford: Blackwell.

Kuhn, W. (1996). *Handling Data Spatially: Spatializing User Interfaces*. Paper presented at the 7th International Symposium on Spatial Data Handling, Delft, The Netherlands.

Lewis, C., & Rieman, J. (1993). *Task-centered user interface design: A practical introduction*. Boulder, CO: University of Colorado, Boulder.

Luo, W., Yin, P., Di, Q., Hardisty, F., & MacEachren, A. M. (2014). A Geovisual Analytic Approach to Understanding Geo-Social Relationships in the International Trade Network. *PLoS ONE*, *9*(2), 1–12. doi:10.1371/journal.pone.0088666

Nielsen, J. (1994). Estimating the number of subjects needed for a thinking aloud test. *International Journal of Human-Computer Studies*, *41*(3), 385–397. doi:10.1006/ijhc.1994.1065

Roth, R. E., Ross, K. S., & MacEachren, A. M. (2015). User-Centered Design for Interactive Maps: A Case Study in Crime Analysis. *ISPRS International Journal of Geo-Information*, *4*(1), 262–301. doi:10.3390/ijgi4010262

Rubin, J., & Chisnell, D. (2008). *Handbook of Usability Testing: How to Plan, Design, and Conduct Effective Tests* (2nd ed.). Indianapolis, IN: Wiley Publishing, Inc.

Shneiderman, B. (1996, September). The eyes have it: A task by data type taxonomy for information Visualizations. In *IEEE Symposium on Visual Languages*. (pp. 336–343). Retrieved from http://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=3922; doi:10.1109/VL.1996.545307

Skupin, A., & Fabrikant, S. I. (2007). Spatialization. In J. P. Wilson & A. S. Fotheringham (Eds.), *The handbook of geographic information science* (pp. 61–79). Oxford, UK: Blackwell Publishing Ltd.

Strötgen, J., & Gertz, M. (2013). Multilingual and cross-domain temporal tagging. *Language Resources and Evaluation*, *47*(2), 269–298. doi:10.1007/s10579-012-9179-y

Wharton, C., Rieman, J., Lewis, C., & Polson, P. (1994). The cognitive walkthrough method: A practitioner's guide. In J. Nielsen & R. L. Mack (Eds.), *Usability inspection methods* (pp. 105–140). New York, NY: John Wiley & Sons.