Invoking a Sense of Orientation in Digital Libraries

Inessa Seifert[1] and Kai-Florian Richter[2]

[1] German Research Center for Artificial Intelligence (DFKI GmbH),
Alt-Moabit 91c, Berlin, 10559, Germany
inessa.seifert@dfki.de
http://www.dfki.de

[2] Transregional Collaborative Research Center SFB/TR 8 Spatial Cognition,
University of Bremen, P.O. Box 330 440, 28334 Bremen, Germany
richter@sfbtr8.uni-bremen.de

Abstract. In our contribution, we will discuss how understanding of visualization and interaction with the information discovery system DiLiA (Digital Library Assistant) [1] can be improved by recurring to properties and principles of human spatial problem solving and navigation in real world environments. We will outline the properties that these two problem domains have in common and also highlight the differences between them. In the end, we will propose a visualization of a data space that is inspired by the discussed principles and also makes use of principles of faceted search. This visualization should invoke in users a *sense of orientation* in scientific literature that is created by intelligently presenting digital libraries' content.

Key words: information visualization, sense of orientation, navigation, digital libraries

1 Introduction

In our contribution, we will discuss how principles of structuring real world environments may support invoking a sense of orientation in users of digital libraries. Quoting Franzius et al. [2]: "To orient ourselves, we mainly need two pieces of information: where am I and in which direction am I heading?" These two questions need to be answered with respect to exploring digital libraries.

To this end, we will discuss structural properties of spatial environments and compare them to the properties of data spaces that encompass scientific publications. We will outline possible actions that allow a person to efficiently solve information seeking tasks and compare them to problem solving steps and strategies that come into operation in physical environments. Finally, we will conclude with a discussion about how the identified principles can be transported into a visualization of scientific literature to provide the desired sense of orientation in a digital library.

In general, the structure of an environment surrounding you gives cues about where you are and what possible actions can be performed next. However, with respect to digital libraries this structure is dynamic, since the topics and the search goals evolve during the information seeking process [3]. Hence, a visualization has to cover this dynamic structure of the information space and to explain how moving through it is possible (in the very moment and in principle). We believe that presenting information on different levels of granularity in a single display will result in the required sense of orientation. That way, users can well understand granularity shifts and abstraction becomes possible. Such information display *integrates relevant multi-granular* information, very much in the way that schematization may be employed for creating visualizations for spatial assistance [4].

The paper is structured as follows: in the next two sections, we discuss the structure of spatial environments and digital libraries, and their mental representation, respectively. Section 4 then highlights commonalities and differences between both structures with respect to navigating through them. In Section 5, we present current trends in information visualization for digital libraries in light of the previous discussions, while Section 6 then details our approach to information visualization. The paper ends with some conclusions and an outlook on future work in Section 7.

2 The Structure of Environments and Their Mental Representation

The structure of an environment, i.e., its layout, has great influence on people's mental representation. Likewise, people's experience and expectations influence how they mentally represent an environment and how they interact with an environment.

2.1 Environmental Structure

In his seminal book "the image of the city" Kevin Lynch [5] laid the foundations for analyzing environmental structure from the perspective of how humans cognize it. He identified five fundamental elements that structure our image of a city: 1) paths; 2) edges; 3) districts; 4) nodes; 5) landmarks. People travel through an environment along *paths*; these paths may meet at *nodes*, which generally describe important strategic places, such as intersections or breaks in transportation. Travel may be restricted by *edges*, which are perceived as boundaries between areas, either only perceptually or as actual physical objects. *Districts* are regions that are perceived as containing common features that their elements share. *Landmarks*, finally, are outstanding features of an environment that gain their significance through physical or social concepts (cf. also [6]).

2.2 Spatial Mental Models

The complexity of an environment strongly influences people's mental models of that environment. In complex environments, people have more difficulty building up a useful mental model [7]. In built environments, which are predominantly under consideration in cognitive science, the complexity of an environment depends on architectural differentiation, the degree of visual access, and the complexity of its layout [8, 9]. In general, mental models of spatial environments are hierarchical [10]. This hierarchization is formed either based on explicit region information provided by the environment, or by building spatial clusters around landmarks (e.g., [11]). Such mental models may contain unrelated contradicting knowledge in different formats (e.g., propositional and pictorial) [12]. Unlike the metaphor "cognitive map" may imply, these models are rather not like 2D survey maps.

2.3 Wayfinding Strategies

Based on how they perceive the structure of an environment, human wayfinding seldom relies on geometrically shortest distance or shortest travel time, as automatic assistance systems (e.g., internet route planners or car navigation systems) usually calculate their paths. Instead, a number of factors determine path choice [13]: next to distance and time these include number of turns, shortest or longest leg first, many curves or turns, first noticed and most scenic route. Further, the deviation angle of how the direction of current movement differs from the direction to the destination may have an influence on path choice [14]. In environments with a perceivable region structure (e.g., districts as defined above or regions formed around landmarks), people rely on this region structure and employ hierarchical wayfinding strategies [15]. In general, paths are not fully planned ahead in every detail, but some options can only be verified and, thus, chosen in situ [16].

3 The Structure of Digital Libraries and Their Mental Representation

Digital libraries are not bounded in their structure by the limitations of physical space, for example, gravity and metrics. However, just as with physical space, interaction and mental representation of their structure depends on people's experience and expectations.

3.1 The Structure of Scientific Literature

A scientific article is characterized by the meta-data that makes it unique: *title*, *author(s)*, *editor(s)*, *year*, publishing *source* (e.g., the name of the journal, or conference proceedings, volume, issuer), *abstract*, and its *text*. Some digital libraries (e.g., ACM digital library[3], CiteSeer[4]) provide further information such as *keywords*, *categories*, and links to the *referenced articles*. Using this information, a

[3] http://portal.acm.org/
[4] http://citeseerx.ist.psu.edu/

data space can be constructed as a network consisting of articles connected to their references, or articles and co-author relations. Such a network introduces topological relations between information items.

Modern digital libraries make this data space accessible to the user via a graphical user interface that usually consists of a search panel and a hit list. The search panel allows for stating a search query that involves a combination of terms and optional Boolean AND, OR, and NOT operators. The hit list includes the results of a query. Each hit list item presents the metadata that belongs to each retrieved document. The user examines the items in a hit list and accesses their relevance. If a document is considered to be relevant, it is usually downloaded (according to the copyright conditions) for further inspection.

3.2 Information Seeking

It is surprisingly easy today to find a specific book, a journal, or an article if the search goal is known. Yet, if the information seeker is not familiar with the targeted topic, search queries are underspecified and most often lead to a huge amount of resulting hits.

Marchionini [17] defines information seeking as "a special case of problem solving. It includes recognizing and interpreting the information problem, establishing a plan of search, conducting the search, evaluating the results, and, if necessary, iterating through the process again."

Bates [3] describes information seeking as a process that starts with either a definition of a broader topic or a single relevant reference. People move through the data space and discover new pieces of information by tracing the references, running through the relevant sources (e.g., journals, conference proceedings), or examining works of selected authors. These actions contribute to new ideas and directions to follow, and consequently new conceptions of search queries as well as better understanding of the search problem. She called this process *evolving search* and compared the integration of newly acquired knowledge fragments to "berrypicking." In doing so, the relevant items are distributed over the data space so that the information seeker has to pick them up from different sources using the strategies described above (e.g. journal runs, citation tracing, etc.).

Obviously, information seeking has a close relation to learning. When searching for information about unfamiliar topic, people try to connect previous knowledge with the newly acquired information. In doing so, people economically reuse the available knowledge structures that involve concepts and relations identified and learned before or directly during a search session [18]. Learning is particularly efficient when the structure which is learned corresponds to the structure of the previous knowledge [19].

3.3 Mental Knowledge of Scientific Literature

Traditionally, information seeking behavior has been studied in connection with some information retrieval (IR) system. Such studies focus on the analysis of the actions performed by users when solving an information seeking problem. For example, Vakkari [20] analyzed the keywords used by students while accomplishing a research proposal for a masters thesis. The traces of keywords indicated the evolving conceptualization of the studied topic. The insights gained from these studies, however, are restricted to the operations (such as the definition of keywords in combinations with Boolean operators) supported by an IR system and do not provide information on how mental representations are actually structured and how people employ them to find relevant information.

In information seeking, people are usually involved in some larger task context, since "search is a means towards some other end, rather than a goal in itself" [21]. For example in academia, scientists search for relevant information when writing an application for a grant, a scientific paper, or preparing a lecture for a university course. Although information seeking is a long studied area, investigations into people's interaction with scientific literature in context of their every day scientific work are rare.

In the scope of this paper, we will refer to one particular study, conducted by Anderson [22], which is focused on information choices of expert scientists over a long period of time in the context of academic work, especially, how expert scientists establish the relevance criteria that guide their search for appropriate literature in large data collections, such as digital libraries. The study describes the relevance criteria that lead to information selection decisions made during search. These criteria are derived from think-aloud protocols collected during multiple interviews and search sessions. The protocols show that experts rely not solely on the so called topicality of a scientific document, but rather rely on subjective judgments that involve various *multidimensional* aspects, for example:

1. a personal connection to the author of an article, or familiarity with an author's work (so called key-authors who coined a research area or a topic),
2. popularity and the impact factor of journals or conference proceedings, i.e., the source of an article where it was published,
3. author's affiliation to a specific organization or institution.

These criteria come into operation simultaneously. Therefore, even an article that fits well in a search query can be discarded in case its authors or its source have a bad reputation. On top of that, personal interaction and communication about scientific topics with other researchers at different conferences or symposia turns out to be a crucial source of information about who works on which topics.

In that, information seeking is fundamentally different from another important process in scientific work, namely double-blind reviewing where authors and affiliations are intentionally blended out. In information seeking, scientists eagerly use this information for judging the relevance of others' work and for guiding their search.

4 Finding Your Way in the Real World and in Digital Libraries

Structurally, spatial environments and digital libraries do not have much in common at a first (and maybe second) glance: a spatial environment is structured through physical reality; it is a metric space, which affords physical effort to get from a spot A to a spot B. Movement is restricted by obstacles (either man-made or natural). In a digital library (browser) no such restrictions apply. No physical movement that would be crucial for getting from one state to another needs to be performed. The structure is not metric to begin with; physical properties, such as gravity, do not play a role.

Still, when navigating such spaces, some important commonalities occur (cf. also [23]). In both worlds, those navigating the space reach specific points where decisions about the further way to take are due. In real-world navigation, these points are referred to as *decision points*. Usually, these points correspond to intersections in a street network where there are several possibilities to continue one's travel. In Lynch's terminology (see above), the sequence of decision points and segments between them form a *path*, the movement pattern of traveling along that path describes a *route* [24]. The ease of navigating decision points depends on their structure (e.g., number of meeting segments) on the one hand. On the other hand, visual or structural cues help to identify decision points and to indicate the further way to take [6, 25]. Such cues might be signage or landmarks, for example. They provide a sense of orientation along a route. As discussed in Section 2, to orient themselves with respect to the larger environment surrounding the route, people also make use of regions.

In digital libraries, no a priory network exists that movement through the content may be performed on. But the sequence of interaction steps while exploring a digital library corresponds to some kind of movement pattern that forms a path where each new state is topologically connected to its predecessor. This way, a path emerges that describes a user's movement through the library—it might also become a branching network, when backtracking to previous states and continuation with a different interaction from there is added to the interaction history. Information seekers may remember these states as the origin of several interaction paths and, thus, as the nucleus of a specific part of the data space. That is, conceptual regions may emerge from the branching in interaction history.

Such interaction paths allow for answering the crucial questions for having a sense of orientation as defined in the introduction: 1) "where am I" (in my interaction sequence)? 2) "where can I go to" (which are useful options at this state)? Just as with paths in the real world, each state in the exploration of the digital library corresponds to a decision point. And just as with real world navigation, visual and structural cues help in identifying the state, answering the "where am I?" question, and in indicating further ways to takes, answering the "where can I go to?" question. Thus, an interface to a digital library is called for that clearly presents the current state in its exploration context and, likewise, clearly indicates which interactions, i.e., which operations using which items, are sensible for further exploration from this state.

Furthermore, background knowledge plays a crucial role in navigation in both worlds. In the real world, background knowledge allows for assistance-free navigation in well known environments, i.e., people just know the way to take.

But such knowledge also helps navigating unknown environments by recurring to knowledge gained in similar environments. For example, knowing how a city is structured, one may infer that buses often run along major streets and that shopping facilities are often located near the main station.

Differences in background knowledge is even more important for navigating digital libraries. As discussed in Section 3.3, scientists rely a lot on information that they have gained through social interaction and as part of their work experience. This knowledge is largely acquired outside a digital library and then used to explore its content. It drives interaction with the presented content, particularly which further "paths" are taken from the choice of possible next steps. Thus, making this additional information available, such as the country or institute the publication has been written at or the journal / conference it has been published in, is an important aspect of supporting navigation in a digital library, especially for the "where can I go to?" question. For experienced scientists, this allows for being quickly able to judge particular publications, for novices it supports gaining the required background knowledge for the research field under inspection.

5 Trends in Interface Design of Digital Libraries

Different metaphors have been used in the context of explaining and strengthening the visual experience of a digital library's structure. The approaches taken so far range from classical simple form-based search panels and hit list components (e.g., google search[5]) to animated three-dimensional hierarchical cone-tree structures that allow for interactive exploration of a data space [26].

5.1 Spatialization

Fabrikant [27] proposed a visualization of different topics as a geographical map; she terms this technique *spatialization*. Related topics are positioned near each other, whereas topics that have nothing in common are far away. Spatial distance between topics enables users to get an overview about relations between various scientific areas at a single glance. By rendering height information in the third dimension, a spatialized data space may show the number of documents contained in a topic, for example. A similar spatial distance metaphor has been used to visualize concept spaces [28].

5.2 Citation and Co-Author Networks

Citation networks visualize references between articles. Co-author networks display relations between researchers who cooperate with each other by co-authoring scientific publications. This type of visualization is useful in identifying citation clusters or groups of closely cooperating researchers. The citation or cooperation

[5] www.google.com

density may indicate interesting emerging topics in a scientific community. The major problem in using network-graphs for information visualization is the potentially high connectivity of nodes. Therefore, it is often very hard to perceive the boundaries between such clusters.

Although spatialization, and citation and co-author networks may seem to be different at first glance, these methods share one thing in common. They reduce the dimensionality of the data space by focusing on selected aspects: topics, citations, or authors. Due to this information reduction important connections between researchers, institutions, and topics are lost.

5.3 Faceted search

Faceted search is a recent approach in interface design that turns back to classical form-based data presentations. In order to facilitate the exploration of data, faceted search interfaces include not only hierarchically organized categories or topics but also offer facets to navigate through the data space[6]. Facets reflect the structural properties of the underlying documents including meta-data, year of publication, research institutions, and also specific characteristics of a document, for example, its format [29]. Information seekers can explore the data space by incrementally selecting and adding different facets in order to interactively refine the resulting hit list.

Digital libraries, such as gopubmed[7] hosted by Transinsight GmbH or AuthorMapper[8] hosted by Springer, implement a combination of the currently proposed visualization techniques described above. Mainly, these digital libraries have a facets-based interface that integrates tools for further analysis of resulting hits. Such tools include bar charts that allow for examining how a research topic is developing over time filtered by different facets (e.g., articles per year according to a selected topic, country, author, keywords, journals, or institutions). Additional tools, such as co-author networks or locations of the corresponding institutions depicted on geographic maps, provide further perspectives on the data space.

Figure 1 illustrates the interface of the gopumed digital library. The facets, including categories, keywords, and technical terms, are on the left side of the screen. The resulting hits are to the right. Users now have the possibility to filter various dimensions to refine the resulting hit list. Users explore the literature contained in the digital library by interactively adding or removing proposed facets.

Faceted search is a promising method for integration and visualization of multiple dimensions relevant for exploring and understanding digital libraries. It forms the basis for our approach of information visualization that goes one step further by providing a compact, relational, and interactive visualization.

---

[6] http://flamenco.berkeley.edu/index.html
[7] http://www.gopubmed.com/
[8] http://www.authormapper.com/

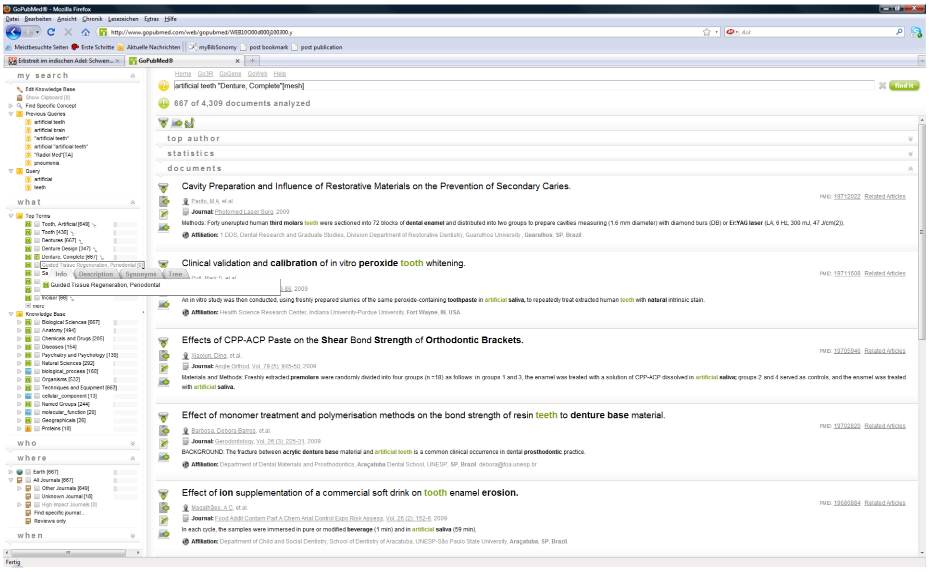


Fig. 1. Example faceted interface of gopubmed (http://www.gopubmed.com/)

6 Multidimensional Query Visualization Approach

The main idea behind the approach pursued in DiLiA [1] is to establish relations among multiple dimensions of a data space and to make them visually accessible to the user. In addition to the current trends and visual features discussed so far, a relational query visualization offers a number of interactive operations that allow for stating new queries, modifying old queries using Boolean operators, and retrieving new relations.

DiLiA integrates different levels of granularity in its visualization. A first step to achieve this is a division of the main panel into two parts (see Figure 2). On the right side, consistent with the digital libraries described above, it contains a search panel and a hit list. The left side of the screen displays relations between search queries formulated by the user during the search.

6.1 Interactive Hit List

The hit list displays traditional meta data that characterizes a scientific publication, such as title, author names, source, abstract, a publishing year, and keywords. Beyond that, the hit list is augmented with technical terms, which are automatically extracted from the abstracts (see [30] for details). One hit is displayed in detail, while additional hits can be accessed by pressing their title bar.

Users have different possibilities for stating a search query. The search panel allows for a free selection of search terms. Authors, titles, keywords, and technical

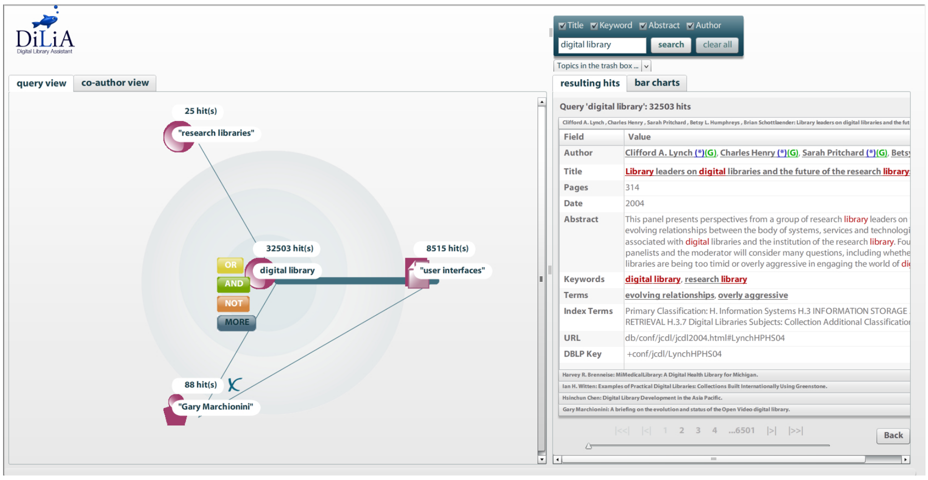


Fig. 2. DiLiA user interface

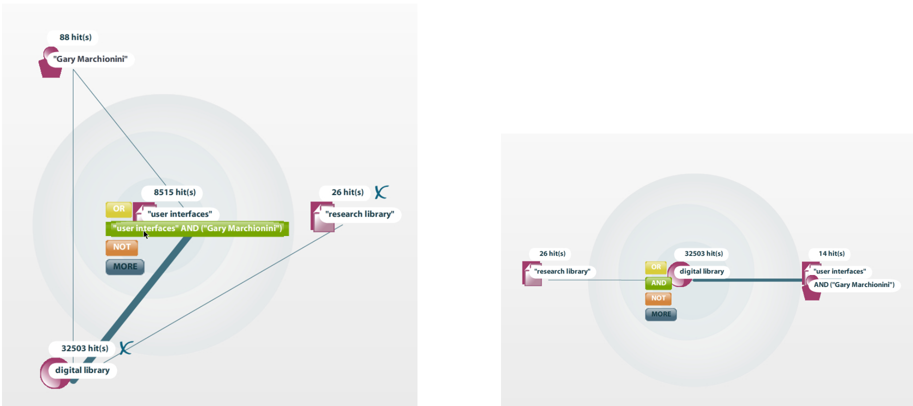
terms are implemented as hyperlinks that enable users to seamlessly invoke new search queries. Each query is visualized as a blob on the left side of the main panel.

6.2 Query View

Each query blob displayed in the query view corresponds to a state in the exploration history (cf. Section 4). Query blobs represent different metadata types, for example authors, keywords, search terms, or organizations. Query blobs are connected with each other via edges that symbolize query intersections. The edge thickness shows how many documents are shared between the queries. This gives users an immediate impression about which Boolean operator can be applied to a pair of query blobs. It supports the "where can I go to?" question as it offers clear hints of what next steps are possible. Users can perform Boolean operations by dragging and dropping the blobs surrounding the central query to the corresponding AND, OR, and NOT panels (see Figure 3). The system suppresses AND and NOT operations if query blobs have no intersections. In doing so, the system helps the user to avoid frustrating "no hits" situations.

Information seekers can browse the content of the query blobs by clicking on them. This operation moves the clicked query blob into the center by an animation and displays the documents contained in it in the hit list. Keeping the currently selected blob in the middle of the display puts it in visual focus and clearly indicates a user's location within the exploration process. It answers the "where am I?" question.

Users can examine the results of performed operations at different levels of granularity: as updated relations between queries (the left side of the screen) or as a hit list of articles (the right side of the screen). Users further may remove a query blob from the view in case it is not needed any more. This allows avoiding information overload and keeping the query view compact and clear. Removed query blobs can be restored from a trash box which is situated under the search panel. The “MORE” button, finally, invokes an online clustering procedure that proposes semantic labels extracted from the documents contained in the query (see Figure 4).



(a) Example combination of an author and a topic

(b) The result of the combination

Fig. 3. Drag-and-drop manipulations of search queries

Information seekers incrementally construct a relational query visualization during their individual exploration of the data space. By applying the AND operator, they refine the search goal. The OR operator allows for broadening the search. The NOT operator can be explicitly applied, for example, to search for articles that are written by less prominent authors. If researchers always only read those authors whom they know, they would easily miss new interesting ideas stemming from young scientists or other scientific communities.

The relational query view integrates information on different levels of granularity. First of all, metadata may be on different levels of granularity, for example, a research field, such as “visualization,” compared to a single author or even paper in that field. Even more, applying Boolean operators results in hierarchical relationships between the newly emerging query blob as a parent of the topics combined with the Boolean operator. To add to this, the AND operator narrows results, i.e., moves to a finer level of granularity, while the OR operator does the opposite. In DiLiA, all these different granularity levels are integrated and connected in a single view without the need for moving up or down hierarchical list or tree views. Thus, information seekers always have an overview of where they are in their exploration as well as easily gain insight in the structure of and relationships in the research field under inspection.

(a) Example semantic labels retrieved from the query "user interfaces"

(b) The result of selection of the proposed semantic labels

Fig. 4. Retrieving and using semantic labels

This way, the relational query view maintains the search steps made by the user, or in other words the traversed *decision points*, by maintaining query blobs and spanning a network between them showing their relationships, both with respect to the content of the library and the exploration history. Having such a multidimensional representation of query results at hand, users can incrementally construct their individual picture of the scientific literature being under investigation. Combining different dimensions in a single visualization provides a better understanding of research activities and connections between topics, authors, or institutions. One can see how many articles a particular author has published to a specific topic. By retrieving additional semantic labels, users may explore additional topics the author has been working on. Such operations provide an overview and at the same time propose new directions for exploration. To sum up, query blobs show the paths taken so far, the relations between them show further steps that can be followed without running into a dead end, i.e., frustrating "no hits" situations.

7 Conclusions and Outlook

This contribution discusses how users may be supported in information seeking in digital libraries. We have argued for commonalities in the structure of real world environments and the structure of a library's data space, and in navigating in both that allow for employing concepts from real world orientation also in the digital world. This enables the creation of information displays that invoke a sense of orientation in the users, which in turn fosters gaining an overview over a scientific field and detecting novel research ideas from related fields or less well-known authors. We have exemplified the discussed principles by presenting DiLiA (Digital Library Assistant) a novel interface for exploring information stored in a digital library.

Future work first and foremost comprises user studies to elicit whether the claims made in this paper, while plausible from existing research, indeed hold. We are currently setting up a first experiment that will shed light on usability issues of the system. First, we will test basic usability issues (learnability, efficiency, memorability, errors, and satisfaction) using the IsoMetrics questionaire [31]. Second, we will conduct a study exploring more specific aspects of interacting with DiLiA, for example, which Boolean operators may be used more intensively than others, which kind of queries may be preferred, and which dimensions are explored. This will provide important feedback for further system design.

In general, surveying and mapping of scientific data has just really started. Commercial online digital libraries hosted by established publishers (e.g., Springer, ACM) provide very good information quality. Yet, the content of such libraries is limited to the articles issued by these publishers, there is still a lot of room for improving exploration of content, and the access to their content is restricted to the organizations who have a subscription. Openly accessible digital libraries, such as DBLP or CiteSeer, are limited to metadata acquired through crawling the web, often without access to the full texts. Unfortunately, the quality of this metadata is poor, important information, like organization or even source, is missing. In light of the large effect social information and interaction has on browsing digital libraries, reliable metadata supporting this social interaction can be expected to increase the quality of information drastically. Since it is to a considerable extend a social venture, technologies developed in connection to web 2.0 may help to collect and exchange the required data on a larger scale.

8 Aknowledgements

The research project DILIA (Digital Library Assistant) is co-funded by the European Regional Development Fund (EFRE) under grant number 10140159. The second other's work is funded by the Deutsche Forschungsgemeinschaft (DFG). We gratefully acknowledge this support and helpful comments by three anonymous reviewers.

References

1. Seifert, I., Kruppa, M.: A pool of topics: Interactive relational topic visualization for information discovery. In: Proceedings of Visual Information Communications International 2009, Springer (2009)
2. Franzius, M., Sprekeler, H., Wiskott, L.: Slowness and sparseness lead to place, head-direction, and spatial-view cells. PLoS Comput Biol **3** (08 2007) e166
3. Bates, M.: The design of browsing and berrypicking techniques for the online search interface. Online Review **13**(5) (1989) 407–424
4. Klippel, A., Richter, K.F., Barkowsky, T., Freksa, C.: The cognitive reality of schematic maps. In Meng, L., Zipf, A., Reichenbacher, T., eds.: Map-based Mobile Services - Theories, Methods and Implementations. Springer, Berlin (2005) 57–74
5. Lynch, K.: The Image of the City. The MIT Press, Cambridge (1960)
6. Sorrows, M.E., Hirtle, S.C.: The nature of landmarks for real and electronic spaces. In Freksa, C., Mark, D.M., eds.: Spatial Information Theory, Berlin, Springer (1999) 37–50 LNCS 1661.

7. Kim, Y.O.: The role of spatial configuration in spatial cognition. In Peponis, J., Wineman, J., Bafna, S., eds.: Proceedings of the Third International Space Syntax Symposium, Ann Arbor, University of Michigan (2001) 49.1–49.21
8. Weisman, J.: Evaluating architectural legibility: Way-finding in the built environment. Environment and Behaviour **13**(2) (1981) 189–204
9. Gärling, T., Lindberg, E., Mäntylä, T.: Orientation in buildings: Effects of familiarity, visual access, and orientation aids. Journal of Applied Psychology **68**(1) (1983) 177–186
10. Hirtle, S.C., Heidorn, P.B.: The structure of cognitive maps: Representations and processes. In Gärling, T., Golledge, R., eds.: Behaviour and Environment: Psychological and Geographical Approaches. Elsevier Science Publishers, Amsterdam, North-Holland (1993) 170–192
11. Couclelis, H., Golledge, R.G., Gale, N., Tobler, W.: Exploring the anchor-point hypothesis of spatial cognition. Journal of Environmental Psychology **7** (1987) 99–122
12. Tversky, B.: Cognitive maps, cognitive collages and spatial mental models. In Frank, A.U., Campari, I., eds.: Spatial Information Theory, Berlin, Springer (1993) 14–24 LNCS 716.
13. Golledge, R.G.: Path selection and route preference in human navigation: A progress report. In Frank, A.U., Kuhn, W., eds.: Spatial Information Theory, Berlin, Springer (1995) 207–222
14. Conroy Dalton, R.: The secret is to follow your nose — route path selection and angularity. In Peponis, J., Wineman, J., Bafna, S., eds.: Proceedings of the Third International Space Syntax Symposium, Ann Arbor, University of Michigan (2001) 47.1–47.14
15. Wiener, J.M., Mallot, H.A.: 'Fine to coarse' route planning and navigation in regionalized environments. Spatial Cognition and Computation **3**(4) (2003) 331–358
16. Wiener, J.M., Tenbrink, T., Henschel, J., Hölscher, C.: Situated and prospective path planning: Route choice in an urban environment. In: CogSci 2008: 30th Annual Conference of the Cognitive Science Society, Washington, D.C. (2008)
17. Marchionini, G.: Information-seeking strategies of novices using a full-text electronic encyclopedia. J. Am. Soc. Inf. Sci. **40**(1) (1989) 54–66
18. Vakkari, P.: Task complexity, problem structure and information actions - integrating studies on information seeking and retrieval. Information Processing and Management **35**(6) (1999) 819–837
19. Heit, E.: Knowledge and concept learning. In Lamberts, K., Shanks, D., eds.: Knowledge, concepts, and categories. MIT Press (1997) 7–41
20. Vakkari, P.: eCognition and changes of search terms and tactics during task performance: A longitudinal case study. In: Proceedings of the RIAO 2000 Conference. (2000) 894–907
21. Hearst, M.A.: Search User Interfaces. Cambridge University Press (2009)
22. Anderson, T.D.: Studying human judgments of relevance: interactions in context. In Ruthven, I., ed.: Proceedings of the 1st International Conference on Information Interaction in Context, ACM (2006) 6–14
23. Maglio, P.P., Matlock, T.: Constructing social spaces in virtual environments: Metaphors we surf the web by. In: Workshop on Personal and Social Navigation in Information Space, Stockholm, Sweden (1998) 138–149
24. Klippel, A.: Wayfinding choremes. In Kuhn, W., Worboys, M., Timpf, S., eds.: Spatial Information Theory, Berlin, Springer (2003) 320–334 LNCS 2825.

25. Richter, K.F., Klippel, A.: A model for context-specific route directions. In Freksa, C., Knauff, M., Krieg-Brückner, B., Nebel, B., Barkowsky, T., eds.: Spatial Cognition IV, Berlin, Springer (2005) 58–78 LNAI 3343.
26. Robertson, G.G., Mackinlay, J.D., Card, S.K.: Cone trees: animated 3D visualizations of hierarchical information. In: CHI '91: Proceedings of the SIGCHI conference on Human factors in computing systems, New York, NY, USA, ACM (1991) 189–194
27. Fabrikant, S.: Spatialized browsing in large data archives. Transactions in GIS **4**(1) (2000) 65–78
28. Zhang, J., Mostafa, J., Tripathy, H.: Information retrieval by semantic analysis and visualization of the concept space of d-lib magazine. D-Lib Magazine **8**(10) (October 2002)
29. Hearst, M.A.: UIs for faceted navigation: Recent advances and remaining open problems. In: Workshop on Computer Interaction and Information Retrieval, Redmond, WA (2008)
30. Seifert, I., Eichler, K., Hemsen, H., Schmeier, S., Kruppa, M., Neumann, G., Reithinger, N.: A digital library assistant - a new approach to information discovery through information extraction and visualization. In: Proceedings of International Conference on Knowledge Management and Information Sharing. (to appear)
31. Willumeit, H., Gediga, G., Hamborg, K.C.: IsoMetrics^{L}: Ein Verfahren zur formativen Evaluation von Software nach ISO 9241/10. Ergonomie und Informatik **27** (1996) 5–12