University of Konstanz
Department of Computer and Information Science

Master Thesis for the degree
Master of Science (M.Sc.) in Information Engineering

Enhancing Collaborative Information-Seeking through Surface and Tangible Computing

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Konstanz, October 4, 2010

Abstract

This master thesis discusses the topic of social interaction and collaboration in digital information-seeking systems. As context of the thesis the "Blended Library", a vision of the library of the future is introduced. Novel interaction paradigms like surface and tangible computing are adopted to approach the flaws of today's information systems in supporting users during collaborative search activities. The main contribution of the thesis is the concept of the "Search Tokens", a tangible user interface for co-located, collaborative information-seeking. After establishing the design rationales and the basic visualization and interaction principles behind the concept an evaluation is presented that explores whether users benefit from the Search Token concept during search activities in groups. The research presented in this thesis shows promising and successful solutions to the problem of co-located, collaborative information-seeking.

Zusammenfassung

Diese Masterarbeit diskutiert das Thema sozialer Interaktion und Kollaboration während des Rechercheprozesses mit digitalen Informationssystemen. Als Kontext der Arbeit wird die "Blended Library", eine Vision der Bibliothek der Zukunft, vorgestellt. Durch die Nutzung von neuen Interaktionskonzepten wie Surface- und Tangible-Computing werden die Schwierigkeiten heutiger digitaler Informationssysteme im Bereich von kollaborativer Interaktion angegangen. Im Kern der Arbeit steht das Konzept der "Search Tokens", einer begreifbaren Benutzerschnittstelle zur gemeinsamen Recherche in der Gruppe. Neben der Herleitung der Designprinzipien und der Beschreibung der praktischen Umsetzung wird auch eine Evaluationsstudie vorgestellt. Sie untersucht, inwieweit die entwickelten Konzepte in der Lage sind, die Benutzer beim kollaborativen Recherchieren zu unterstützen. Die in dieser Arbeit vorgestellten Lösungen und Konzepte haben sich dabei als erfolgreich und für die weitere Bearbeitung als vielversprechend erwiesen.

Publications

Parts of this thesis were published in:

- Demarmels, M., Huber, S., & Heilig, M. (2010). Meet Me in the Library! In SIDeR 2010 – Ingredients in Gradient (pp. 61—66).
- Heilig, M., Demarmels, M., Allmendinger, K., Gerken, J., & Reiterer, H. (2010). Fördern realitätsbasierte UIs kollaborative Rechercheaktivitäten? In Mensch und Computer 2010 – Interaktive Kulturen (pp. 311—320).
- Heilig, M., Demarmels, M., Huber, S., & Reiterer, H. (2010). Blended Library – Neue Interaktionsformen für die Bibliothek der Zukunft. i-com – Zeitschrift für interaktive und kooperative Medien, 01/2010, (pp. 46—57).
- Reiterer, H., Heilig, M., Rexhausen, S., & Demarmels, M. (2010). Idee der Blended Library – Neue Formen der Wissensvermittlung durch Vermischung der realen und digitalen Welt. In Ein neuer Blick auf Bibliotheken (pp. 108—116).
- Heilig, M., Demarmels, M., Rexhausen, S., Huber, S., & Runge, O. (2009). Search, Explore and Navigate - Designing a Next Generation Knowledge Media Workbench. In SIDeR 2009 – Flirting with the Future (pp. 40—43).

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1 Introduction

Many theoretical models concerned with information-seeking (Kuhlthau, 1993a)(Ellis, 1989)(Evans & Chi, 2008) expose the essential impact of social interaction and collaborative work during the information-seeking process. However, the hardware that is used to realize today's information-seeking systems often is a limiting factor in supporting these aspects sufficiently. Desktop and terminal computers operated by mice and keyboards are only conditionally applicable for collective work (Amershi & Morris, 2008). Other reasons emerge from the visualization and interaction techniques used by digital information systems that in most cases are designed as single-user applications.

One approach to solve these problems is the distribution over the conjoint use of various (remote) devices, as for example proposed by (Hoare & Sorensen, 2006). But through the projection of social interaction out of the real world, into the digital word many crucial aspects like eye contact, facial expressions, gestures and posture during discussions disappear. The question is how the human-computer interaction can provide solutions for the flaws in supporting the information-seeking process described by the models of information science.

Multitouch technology and tabletop displays constitute new approaches to co-located, collaborative work with digital data. Their horizontal form factor and the possibility to manipulate them simultaneously via touch democratize interaction among groups of users and hence advance collaboration like it is shown in several research projects, e.g. (Morris, Paepcke, & Winograd, 2006)(Isenberg & Fisher, 2009).

Furthermore, they offer a natural way to access information and functionality through more direct interaction. The embodiment theory that increasingly receives attention in human-computer interaction makes a good case for this assumption (Gibbs, 2006). This theory from cognitive science shows, that our cognitive development is strongly connected with the physical and social interaction with objects and creatures in our environment.

These findings and the technological progress in the field of multimodal interaction as well as tangible and social computing are covered by a new paradigm called reality-based interaction (Jacob et al., 2008). Hereby, the general goal is to orient the interaction with computers on the real, non-digital world and create a more reality-based and hence more natural interaction.

Focusing on the processes involved in information-seeking, it is essential to develop tools that let groups of people socially interact among each other and make optimal use of the human skills by applying adequate technologies. Accordingly, the goal is the blending of social- and reality-based interaction with the virtual information-seeking abilities of computers.

For this Master's Thesis the following research questions have been formulated:

1. **Design goals:** What are the most important design goals to best support the development of a new information system that supports collaboration in information-seeking?
2. **Basic principles:** What basic interaction and visualization principles can be used to design a user interfaces for collaborative information-seeking supporting the defined design goals?
3. **Realization:** How can these principles be formed to a concrete design?
4. **Evaluation:** Can users benefit from the principles in the designed concept?

This thesis is structured as follows: After an introduction to the basic theoretical foundations presenting new paradigms of human-computer interaction and theoretical models of information-seeking, the context of the thesis will be framed by introducing the idea of the Blended Library, a vision of a knowledge work concept in the library of the future. A related work section will lead to the main part of the thesis – the concept of the Search Tokens, which introduces a tool for co-located, collaborative information-seeking. After the description of the evaluation that was carried out to test the potential of the new concept the thesis ends with a conclusion discussing the outcome and giving an outlook on future work.

2 Theoretical Foundations

This chapter is concerned with the theoretical foundations of the thesis. It shows how the latest insights of cognitive science and human-computer interaction, like the embodiment theory (Gibbs, 2006) or the concept of reality-based interaction (Jacob et al., 2008), changes the way people will interact with digital information. By further presenting two theoretical models of information-seeking (Kuhlthau, 1993a)(Ellis, 1989) an introduction to the problem domain of knowledge work will frame the context of this thesis. The new concepts for collaborative information-seeking in co-located environments that will be presented as main contribution of this thesis are strongly founded on the work that is introduced in this chapter.

2.1 Cognitive Science and New Interaction Techniques in Human-Computer Interaction

To understand the new approaches in the field of the human-computer interaction, which will be introduced later in this chapter, first, a look at the evolution of "users interacting with computer systems" will be given. In essence there are three major steps in this evolution: command language interfaces, graphical user interfaces with direct manipulative input devices and natural user interfaces with reality-based interaction techniques (see Figure 1).

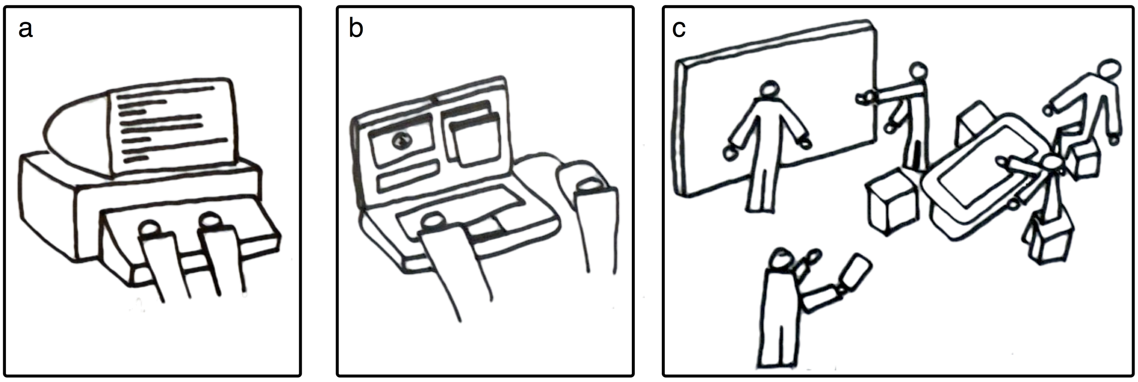

Figure 1: The Evolution of Human-Computer Interaction – a) command language user interface – b) graphical user interface (GUI) – c) natural user interfaces and ubiquitous computing.

2.1.1 The Command Language Era

First interactive computer systems, introduced decades ago, were solely controlled by command language. Soon computer keyboards were used as input devices and non-graphical computer screens as output devices. The communication between user and computer through a command language interface is a textual dialog using an input language that follows very strict semantics and syntactic rules. Interacting with such a computer system is hard to learn and not regularly used commands are easily forgotten.

The user interface does not reveal what data is processed and how it is going to be altered by the commands that are entered into the system. Difficult concepts of what will happen have to be envisioned by the operator of the system before a command is executed, resulting in a very high cognitive load for the user. This can lead to severe mistakes like data loss or false calculations, sometimes even without getting noticed. Compared to today's technologies, the possibilities of what can be achieved with such systems, particularly in the field of personal computing, are very restricted.

Nevertheless, command language based computer systems are still successfully used in many contexts (e.g. administration of server computers, databases, etc.). Some concepts of command language interfaces have even been translated into modern application domains, which are daily used by experts and non-expert users (e.g. web search engines like Google[1], Yahoo![2], etc.).

2.1.2 The Graphical User Interface

The next stage of the user interface evolution was the introduction of the graphical user interface (GUI). By means of this concept the objects that a user is manipulating and the relations among them are represented through graphical artifacts on a computer screen. By providing a more intuitive interface between computer and user, the implications of the user's interaction with the system is made more obvious and easier to understand.

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[1] http://google.com – visited October 4, 2010

[2] http://yahoo.com – visited October 4, 2010

The explicit representation of digital objects, user instructions and work processes form a model world that visually represents all possible interactions with the computer system. The desktop metaphor (Smith, Irby, Kimball, & Harslem, 1982) arose as the most dominant model used with GUIs, which it is still in most of today's personal computer systems. Hereby the main functions of a digital system are mapped to the attributes of a real-world office. For example: folders are holding multiple files, dragging files to a virtual trash bin will delete them, files can be placed on a desktop, etc. Also other metaphors like menus to select functions, virtual buttons to execute instructions, tables to represent data, etc., have become standard user interface elements.

Besides the graphical capabilities of the computer systems, also new interaction possibilities were taken into account (e.g. computer mice, track balls, track pads, flight sticks, etc.) enabling users to more directly interact with a computer in comparison to the solely keyboard-based interaction from earlier systems. Later on, other input devices like digital pens and touch displays complemented the possible interaction techniques.

The graphical representation of digital objects and functions reduces the cognitive load the user has to deal with. This helped to familiarize the power of computers with non-expert users, since computer systems with GUIs generally are much easier to learn, understand and handle.

2.1.3 Stepping Towards a New Age of Human-Computer Interaction

Based on insights gained in cognitive psychology the concept of embodied interaction (Dourish, 2004) again questions today's interaction paradigms. New findings in the field of cognitive science and concepts like ubiquitous computing (Weiser, 1991) (Weiser, 1993) as well as augmented reality (Wellner, Mackay, & Gold, 1993) have triggered the next stage in the evolution of human-computer interaction and open new ways how people interact with the digital world. Among other high-level design principles, Dourish states:

> *"Embodied interaction turns action into meaning."* (Dourish, 2004)

Embodied interaction makes a case for the importance of physical interaction with real-world objects and social cooperation among human beings, also when interacting with the digital world. (Klemmer, Hartmann, & Takayama, 2006) explain that:

> *"...thought (mind) and action (body) are deeply integrated and ... co-produce learning and reasoning."* (Klemmer, Hartmann, & Takayama, 2006)

In contrast to earlier interaction paradigms, embodied technologies are a part of the environment and they will participate in the users' interaction with the digital and physical world. Selected functionality can for example be mapped onto interaction with physical user interface elements. Tangible user interfaces (Ishii & Ullmer, 1997) represent a user interface concept that supports this form of embodied interaction.

One deduction of the embodied cognition theory for designing interaction concepts for new computer systems is that a rich set of different interaction techniques should be provided. The target is to let users benefit from all their senses and support all their physical and social abilities. In addition to the mentioned tangible user interfaces, many other technologies, like multitouch displays, gesture recognition, body tracking, speech input, etc., are becoming more and more important in the attempt to support such a multimodal interaction (Oviatt, 2003).

Besides technology and interaction techniques the awareness and integration of the users' social environment into work processes is essential for the new paradigms of human-computer interaction. The concept of social computing attends to the fact that in the real world many problems and tasks, like research and knowledge work in business and scientific environments, visiting museums or exhibitions, buying a car, etc., are often handled as group activities. To support this collaborative work it is crucial to integrate the users' social abilities of interpersonal communication and interaction into newly developed technologies and applications.

2.2 Reality-Based Interaction

The term "reality-based interaction" (Jacob et al., 2008) unifies a large set of the above-mentioned interaction techniques and emerging concepts of cognitive science as well as human-computer interaction. It represents a new interaction paradigm and a framework that is used to understand and relate different approaches in the field.

The main goal of reality-based user interfaces is to found interaction with the computer – or better with the digital world – on the interaction with the real, physical world. This way the user interface should become more intuitive because the interaction concepts are omnipresent in the real world.

The concept of reality-based interaction focuses on four themes (see Figure 2) that here have been augmented with examples to better describe their essence.

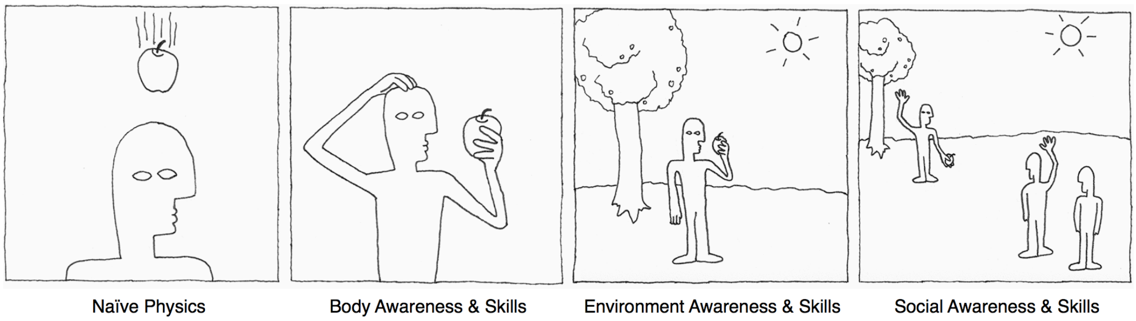

Figure 2: The four themes of reality-based interaction – image from (Jacob et al., 2008).

Naïve Physics – This theme takes the common sense knowledge about the physical world into account. User interfaces that follow the reality-based interaction paradigm have to respect the human perception of basic physical principles like gravity, friction, velocity, persistence of objects, etc. Such computer systems will describe themselves to the user in the way people generally think about the physical world. The user interfaces will simulate, or actually use, properties of the real world and its naïve physical rules. Examples for this theme are scroll panels that simulate inertia and will not immediately stop scrolling when the actual user interaction stops, but will behave like physical objects with mass and friction would do. Also the use of real physical user interface elements, like tokens in tangible user interfaces, belongs to this theme.

Body Awareness & Skills – Body awareness refers to the fact that people have a good understanding of their bodies and know what they are physically capable of. They are aware of the relative position of their limbs, what motion range they have and they are accustomed to the senses that can perceive different impulses of the physical environment, like sensing tangency, perceiving sound, visual inputs, etc. Also, people are able to coordinate multiple body movements (limbs, head, eyes, etc.) all at once. Such capabilities can be used for new input techniques in human-computer interaction. Examples are two-hand or multi finger interaction with a multitouch display or whole body interaction, for example in video games that use body tracking technology to let the user interact with the digital world (e.g. Kinect™ for Xbox 360®[3]).

Environment Awareness & Skills – People, as well as all other physical artifacts, have a physical presence in the real world. Through these artifacts and other landmarks humans are able to spatially understand their environment. Visual landmarks help people to orient themselves in a spatial environment and through objects in this environment they are able to alter it. In virtual and augmented realities these human capabilities can be used to give people clues to better understand the virtual environment. Virtual objects known from the real world can provide help in distance and size estimation. Other use cases are context aware systems, which for example calculate the position and orientation of a user to then decide where and what information has to be displayed.

Social Awareness & Skills – Generally, people are aware of the presence of others around them. They have skills that allow social interaction among each other. This communication can happen in verbal and non-verbal forms (e.g. through gestures or facial expressions). To support collaborative work, it is crucial to take this theme of reality-based interaction into account when designing computer systems. Tangible user interfaces for example enable the exchange of physical objects among the users of a system, which is also an important part of social interaction in the real world (e.g. handing over a key to physically manifest the assignment to go and get something from another room). Additionally, multitouch tables permit multiple users to interact simultaneously with a common view on digital information.

Reality-based interaction makes a good case for the new trends in the human-computer interaction mentioned in section 2.1.3 – Stepping Towards a New Age of Human-Computer Interaction. Different input techniques should enable multimodal interaction to take advantage of the physical capabilities of the users. To improve the understanding of digital systems, user interfaces should be based on the rules of the physical world. Also the everyday knowledge of the users should be regarded as instrument to design simply operable and effective computer systems. Furthermore, computer systems should respect the social skills of users, for example to enable collaborative

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[3] http://www.xbox.com/kinect – visited October 4, 2010

work. The new interaction concepts introduced in this thesis will incorporate the four themes of reality-based interaction.

2.3 Supporting the Users' Work Processes

Besides new visualization and interaction techniques, it is crucial to fully understand the users and their context, both physical and intellectual (Dreyfuss, 1967). Computer systems should not only be seen as tools that support tasks like writing text, calculating data, collecting information, etc., but should also be aware of the broader work processes of the users:

- What do the users want to achieve?
- Where do they come from?
- Where are they heading?
- What is their overall goal?
- How do all the necessary steps to achieve this goal look like?
- How can they best be assisted to reach their goal?

In this thesis the context of information-seeking and knowledge work is used to showcase how surface and tangible computing can enhance co-located, collaborative work. Therefore, the next sections will introduce the domain "information-seeking" and give an overview of theoretical models behind it. In the studies that led to these models people have been observed with a strong focus on their overall working processes during information-seeking and knowledge work.

2.3.1 Problem Space "Information-Seeking"

Nowadays, accessing digital information spaces such as personal data, online databases or the World Wide Web is a daily activity of nearly every individual. But still, information-seeking for job-critical data or to write a scientific article is a very demanding task. One reason for this is the continuously growing complexity of information spaces, resulting from the increasing quantity and heterogeneity of information objects and the relations between them. Another cause is the difficult execution of a multifaceted individual creative workflow (Kuhlthau, 1993a)(Shneiderman, 2003) within today's digital information systems. Such a workflow contains various activities like information-seeking, information management or archiving of information objects. The majority of the available tools focus on assisting users in single aspects of such a workflow like for example the very important task of searching for specific information (see for example MedioVis[4] and (Gerken et al., 2009)).

Most of these tools are isolated applications that are hard to integrate into a person's creative workflow. Content and functionalities are scattered over dozens of applications, websites, storage formats, interaction models and devices – challenging the user's cognitive skills respectively. This often leads to the necessity for workarounds, resulting in a destructive degree of complexity and "information fragmentation" (Karger & Jones, 2006).

There are several research works that analyze the information-seeking behavior of users in a theoretical manner and provide insights into the bigger picture of the work processes involved (Kuhlthau, 1993a), (Ellis, 1989), (Marchionini, 1995). This scientific work is meant to help designing systems that better support knowledge workers. The next sections will give a short introduction into two information-seeking models: Kuhlthau's Information Search Process (Kuhlthau, 1993a) and Ellis' Behavioral Approach to Information Retrieval System Design (Ellis, 1989). These two theoretical models were selected because they were verified in multiple studies and they are well accepted in the information-seeking community.

2.3.2 Kuhlthau's Information Search Process

Kuhlthau's Information Search Process (ISP) (Kuhlthau, 1993a) describes information-seeking as a broad, higher level process. She states that from a user's perspective the primary objective of information-seeking is not to collect information, but to accomplish the task that initiated the search ("seeking meaning"). The ISP is based on empirical research with secondary school students, diverse library users and people in other workplaces (Kuhlthau, 1993a)(Kuhlthau, 1993b)(Kuhlthau & Tama, 2001)(Kuhlthau, 2003). Kuhlthau's model involves six stages that are lived through by information workers:

1. **Initiation** – Recognizing a need for information, becoming aware of a lack of understanding.

[4] MedioVis is a visual information-seeking system developed by the HCI Group of the University of Konstanz. http://hci.uni-konstanz.de/MedioVis – visited October 4, 2010

2. **Selection** – Identifying the general topic to be investigated, selecting the approach judged to have the greatest potential for success.
3. **Exploration** – Extending the personal understanding of the general topic by investigating information on its matters.
4. **Formulation** – Formulating a focused perspective of the topic to concentrate on.
5. **Collection** – Collecting and processing specific information on the focused topic.
6. **Presentation** – Searching to complete remaining gaps in the understanding of the focused topic, preparing to use the gathered information for presenting it in some form.

Besides the tasks that define each stage of the process, every stage involves feelings that are encountered, thoughts that come up and actions that are carried out to progress the information-seeking work (see Table 1). For example uncertainty is a feeling that tends to be encountered in the first stage, where no clear picture of the problem to solve exists, whereas satisfaction might be a feeling encountered at the end of the process, given the information-seeking process has come to a successful end. In early stages of the process thoughts might center on completing the assignment that led to this information search and change to a more personal interest in the topic as the ISP progresses.

<table>
<tr><th></th><th>Initiation</th><th>Selection</th><th>Exploration</th><th>Formulation</th><th>Collection</th><th>Presentation</th></tr>
<tr><td>Feelings</td><td>uncertainty</td><td>optimism</td><td>confusion
frustration
doubt</td><td>clarity</td><td>sense of direction / confidence</td><td>satisfaction or disappointment</td></tr>
<tr><td>Thoughts</td><td>vague</td><td></td><td></td><td>focused</td><td colspan="2">increased interest</td></tr>
<tr><td rowspan="2">Actions</td><td colspan="3">seeking relevant information</td><td colspan="3">seeking pertinent information</td></tr>
<tr><td></td><td>exploring</td><td></td><td></td><td>documenting</td><td></td></tr>
</table>

Table 1: The different stages of Kuhlthau's ISP and the involved feelings, thoughts and actions – from (Kuhlthau, 1993a).

An important role in the work process is ascribed to mediators. These are persons that can intervene and help the information worker keeping on the right track throughout the different stages of the ISP. Such mediators are often domain experts for either the research topic or information-seeking per se (e.g. colleagues, fellow students, tutors, librarians, etc.). Such teamwork is often crucial for a successful outcome. Thus, supporting collaborative work is an essential feature of an information-seeking system and will also be an important aspect of this thesis.

2.3.3 Ellis' Behavioral Approach to Information Retrieval System Design

Ellis proposes another theoretical model of information-seeking (Ellis, 1989). Over the years several publications have supported this model by observing information-seeking behavior of academics across several scientific disciplines (Ellis, 1989)(Ellis, Cox, & Hall, 1993)(Ellis & Haugan, 1997)(Meho & Tibbo, 2003). The model consists of six different information-seeking characteristics, which in contrast to Kuhlthau's ISP do not necessarily have to be regarded as rather sequent steps through the process. At any given time it is possible that more than one of any of these behavioral characteristics are carried out:

- **Starting** – Activities characteristic of the initial search for information.
- **Chaining** – Following chains of citations or other forms of referential connection between materials.
- **Browsing** – Semi-directed searching in an area of potential interest.
- **Differentiating** – Using differences between sources as filters on the nature and quality of the material examined.
- **Monitoring** – Maintaining awareness of developments in a field through the monitoring of particular sources.
- **Extracting** – Systematically working through a particular source to locate material of interest.

Throughout following studies, three additional characteristics were observed: Verifying and Ending by Ellis (Ellis, Cox, & Hall, 1993) and Information Managing by Meho and Tibbo (Meho & Tibbo, 2003):

- **Verifying** – Checking the information and sources found for accuracy and errors.
- **Ending** – The assembly and dissemination of information or the drawing together of material for publishing.

- **Information Managing** – Filing, archiving and organizing information collected or used in facilitating research.

Ellis states that every person finds herself in different unique circumstances during information-seeking activities. Therefore individual information-seeking patterns will evolve. The behavior characteristics above should be seen as a feature set of a model that supports all possibly useful patterns that an information worker might want to carry out. Based on this behavioral approach (among other theoretical models) (Evans & Chi, 2008) propose the explicit integration of social aspects into information-seeking (see section 4.1.1 – Social Search).

2.4 The Blended Interaction Paradigm

The essence of the work presented in this chapter builds the theoretical foundation of the new concepts for collaborative information-seeking that will be introduced as main contribution of this thesis. By providing high-level design goals that help forming practical solutions this foundation contributes to the answer of the defined research question (design goals). Four topics can be extracted, which at the Human-Computer Interaction Group at the University of Konstanz[5] are referred to as the paradigm of "blended interaction":

Personal Interaction – The topic of Personal Interaction is concerned with how a user interacts with a computer system. The goal is to provide natural user interfaces that are based on the interaction with the real world as it is also proposed by the first three themes of reality-based interaction (Naïve Physics, Body Awareness & Skills and Environment Awareness & Skills).

Social Interaction and Communication – This topic takes the social environment of the users into account. The theoretical models of information-seeking show that social interaction and communication plays an important role in the users' work process. Also the fourth theme of reality-based interaction (Social Awareness & Skills) states that people should be able to apply their social abilities when interacting with computer systems. Therefore, new concepts of knowledge work systems should support the social conventions users are accustomed to from their real-world experience.

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[5] http://hci.uni-konstanz.de – visited October 4, 2010

Work Processes – The topic of work processes is concerned with the bigger picture of what users want to achieve. Many applications provide solutions for specific knowledge work tasks, but fail to support users in their overall work process. This topic states that the creative processes of the users should be the central point where new concepts have to be integrated in.

Physical Environment – This topic addresses how the real-world environment of users influences the interaction with the computer. Creative work is often bound to specific locations (e.g. libraries, meeting rooms, construction sides, etc.). This has implications on the character of computer systems and on how the user can interact with them. The goal is to adapt digital systems to the challenges the physical environment sets and to naturally integrate this environment into the interaction with the computer system.

Key Aspects and Conclusion

- After decades of command language user interfaces followed by today's graphical user interfaces we are now stepping towards new a new age of human-computer interaction.
- Reality-based interaction proposes a new paradigm in human-computer interaction proposing the four themes: naïve physics, body awareness & skills, environment awareness & skills and social awareness & skills.
- Theoretical models of information-seeking like Kuhlthau's "Information Search Process" or Ellis' "Behavioral Approach to Information Retrieval System Design" provide insights into the users' information-seeking processes.
- The new approaches of human-computer interaction can be summarized by the idea of "blended interaction", concentrating on the four topics: personal interaction, social interaction and communication, work processes and physical environment.
- The new concepts presented in this thesis are based on these theoretical foundations.

3 Context of the Thesis

In this thesis the context of the library is used to showcase the concrete concepts for collaborative information-seeking, enhanced by surface and tangible computing. This chapter is meant to introduce this context by showing the vision of the "Blended Library" (Heilig, Demarmels, Huber, & Reiterer, 2010)(Reiterer, Heilig, Rexhausen, & Demarmels, 2010), a concept that combines (or blends) the digital information space and real-world artifacts and facilities found in the library. A short scenario will show how the Blended Library works and how the broad processes of information-seeking and the concepts of reality-based interaction are supported by this idea. At the end of the chapter collaborative information-seeking will be highlighted to set the focus on the core topic of this thesis. By exposing concrete design suggestions the definition of the Blended Library, which builds upon the theoretical foundation introduced earlier, contributes to the answers to two of the defined research questions (design goals and basic principles).

3.1 The Blended Library

For centuries, real-world libraries were in a monopoly position as provider of information and knowledge in the public domain. However, through the ongoing digitalization and the spreading of the World Wide Web as one of the most important information providing technologies this monopoly is fading away more and more. The new generation of computer based information systems is able to provide access to virtual unlimited digital information, "every time and everywhere" (McCullough, 2004). Knowledge workers are now able to access all sorts of information sources (e.g. online databases, websites, e-books, online magazines, online journals, scientific articles, etc.).

State-of-the-art digital information systems provide advanced functionalities like full-text search, textual filtering or sorting of search results, etc., which cannot be accessed through analog media. With digital systems it is furthermore possible to generate and use additional metadata, for example gained through user ratings, user reviews, comments and digital annotations or through social tagging. Such metadata becomes important when the quality of a specific information item or an information source has to be evaluated by a knowledge worker as proposed by Ellis (Ellis, Cox, & Hall, 1993) in the Verifying characteristic (see section 2.3.3 – Ellis' Behavioral Approach to Information Retrieval System Design).

In contrast, real-world libraries provide many other advantages. They cannot be seen solely as a storage space for books and other media. Through their sophisticated interior design they are able to physically align knowledge utilizing the spatial order of the contained information artifacts and setting them into relation to each other. People unconsciously develop strategies to make use of this sort of meta-information, which is called "spatial literacy" (McCullough, 2004). Users for example observe the design and the age of book covers and the thematic surrounding of a book in the shelf. Also the number of other people nearby or the location of a bookshelf relative to the typical walking routs in the library or to other important spots like information terminals, copying machines, etc. provide users with additional meta-information.

Another important aspect of real-world libraries is their role as social meeting point especially in the academic context. Often facilities like workstations or even special rooms or cubicles are provided for the users. These infrastructures let people work in the atmosphere of concentration and calmness that surrounds most libraries. Furthermore, most of the larger libraries have librarians who can help the users through their expertise in the field of interest or with their knowledge of information-seeking and the involved processes (Kuhlthau, 1993a).

One fundamental advantage of libraries is the real media (books, magazines, newspapers, etc.) that is available to the users. Many attributes of physical information artifacts just cannot be reproduced by digital information systems. A book for example provides a natural way of reading, including physical interaction, like turning pages, feeling the weight of the book, etc. A real book, in contrast to an e-book, not solely uses the visual channel of the reader. Physical interaction allows for example to quick read through a section or just scan through a book to make decisions on its relevance. In some studies even a so-called "serendipity" effect is described (Foster & Ford, 2003), which lets users generate new thoughts and ideas while scanning through physical books.

A lot of information objects do not exist in a digitalized form and are just available as physical artifacts. To access such information the library plays an essential role. But also digital information sources (e.g. scientific articles, e-magazines, etc.) are often part of a subscription model. Libraries, and the institutions they are affiliated to, can provide access to such information sources. Generally this access is limited to the local area computer network of these institutions and the library (see for example the Library of the University of Konstanz[6]).

Most digital information-seeking systems (or digital libraries) are implemented using PC, mouse and keyboard settings and thus are designed mostly for single user interaction. There are efforts to simulate and integrate some of the natural, social concepts people use in the real world, into digital systems. Social tagging, user ratings and digital annotations are for example attempts to integrate communication concepts into digital information systems. Such mechanisms can provide a lot of additional value for the users. However, despite all efforts to bring digital information systems closer to real-world interaction, most of them are still seen as passive information storage spaces (Adams & Blandford, 2005). People's individual social and physical capabilities are not respected well enough.

With the idea of the Blended Library a vision is proposed that implements strategies to solve the described problems and that brings the advantages of both, the digital and the physical world of information-seeking and knowledge work together. The core concepts behind the Blended Library are based on the blended interaction paradigm (see chapter 2 – Theoretical Foundations), which includes the thoughts of reality-based interaction and the awareness of the broader processes involved in information-seeking.

3.2 Key Concepts of the Blended Library Information System

The idea of the Blended Library goes beyond an application for searching in an online catalog. It involves supporting users in various information-seeking tasks, multiple physical contexts, and diverse social activities. Still, the user interface to interact with the digital information in the Blended Library plays a key part in the concept. Several scenario-like scenes illustrate some of the most significant concepts of the Blended Library information system (see Figure 3—Figure 9). Many of these concepts have been published (Heilig, Demarmels, Rexhausen, Huber, & Runge, 2009) as a design study of a "Knowledge Media Workbench" (Eibl, Reiterer, Stephan, & Thissen, 2005) to support the workflow of creative information work in a unifying workspace.

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[6] http://www.ub.uni-konstanz.de – visited October 4, 2010

3.2.1 Representing Information Objects and Interacting with the System

The fundamental visualization and interaction paradigm of the Blended Library information system is the idea of a Zoomable Object-Oriented Information Landscape (ZOIL) (Jetter, Gerken, Zöllner, & Reiterer, 2010). Within this paradigm, an information landscape of virtually infinite size serves as starting point for the exploration of the information space. Digital information objects are projected onto this information landscape. Users are able to navigate in the landscape with zooming and panning operations (Lindell & Larsson, 2005), which translate movement and navigation from the real world (e.g. approaching and striding away of a physical object) into the digital information system. The navigation techniques of ZOIL take advantage of the human abilities of visual-spatial orientation and remembering visual "landmarks" (Perlin & Fox, 1993). By employing these concepts, users are able to utilize natural and intuitive operations as search strategy in digital media collections.

The more the user zooms into the content the more details and functionalities are revealed by a "semantic zooming" approach (see Figure 3), following Shneiderman's visual information-seeking mantra:

> *"Overview first, zoom and filter, then details-on-demand."* (Shneiderman, 1996)

Thus, available functionalities such as playing a video or accessing a website that provides further information are always coupled with the information object itself, as it is proposed by object-oriented user interfaces (Collins, 1994).

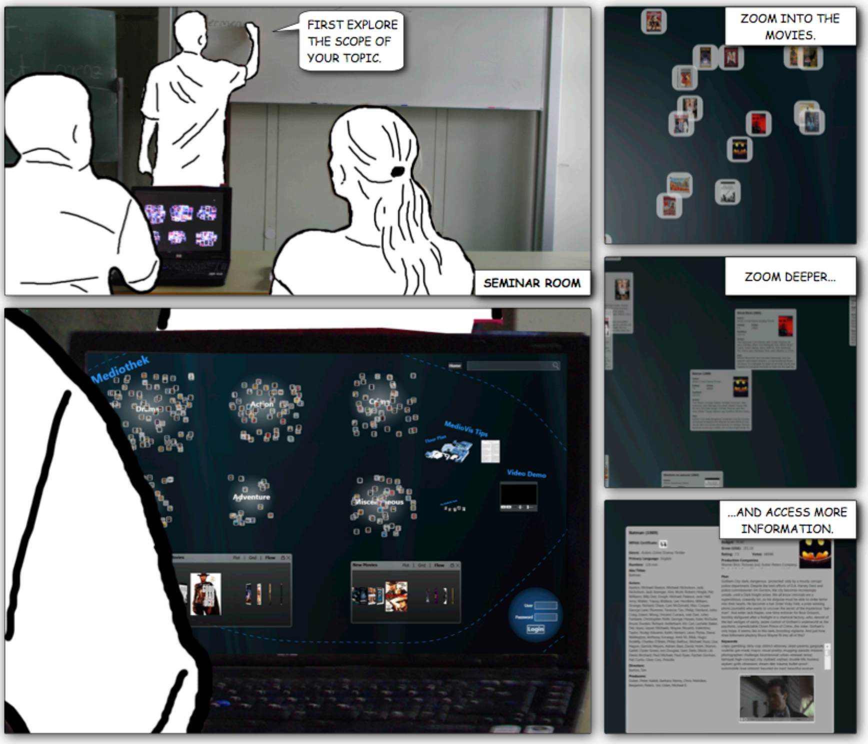

Figure 3: The Blended Library Scenario – The professor and his students are exploring a movie database during the seminar lecture.

Scenario – The characters of this scenario will be shown in different real life situations throughout their work on a term paper for a media science seminar with the title "Comic Book Adaptations in Cinematics". In the first scene (see Figure 3) the students are attending a lecture of this seminar. The professor is giving the assignment for the term paper. In groups of three, the students will have to pick a specific movie character to investigate in and write about. The first task they carry out is to browse through the collection of all relevant movies, looking for interesting and exciting comic characters. The students use their laptops right inside of the seminar room to access the movies by zooming into the digital information objects.

3.2.2 Search, Filter, Explore

The Blended Library information system integrates an analytical search and filter concept directly into the zoomable information landscape. The use of standard user interface elements like windows and lists to represent search results is withdrawn, linking the semantic importance of information objects to their visual size on the information landscape. Users are able to enter text queries into a search field (see Figure 4). With each key press, the visual representation of matching objects expands. Through the concept of dynamic queries (Ahlberg, Williamson, & Shneiderman, 1992) and sensitivity (Tweedie, Spence, Williams, & Bhogal, 1994) information objects that match the current query are highlighted instead of completely removing all non-matching objects from the dataset. With this technique, the attention of the user is automatically directed towards media objects of current interest within the information landscape.

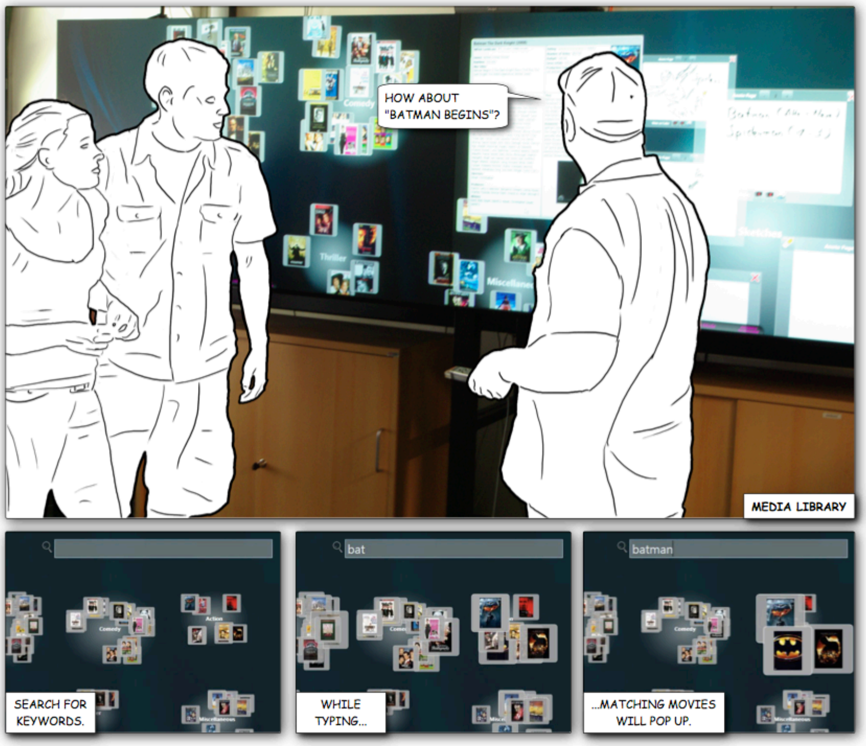

Figure 4: The Blended Library Scenario – The tutor helps the study group to find the most interesting topic to write about.

After the groups for the assignments have been formed and the students have gained an overview of the topic by individually browsing through the information space, they meet with their tutor in the library of the university. The tutor has been supervising this seminar since several semesters. Therefore he is able to assist the group's topic selection by pointing out different movie characters that in past term papers have led to interesting and good work. He also tries to subtly direct the student's investigations to a path of highest probability for success. Different search and filter mechanisms are applied in front of a large wall display (see Figure 4) to support the group's decision process on a concrete topic for the term paper.

In the concept of the Blended Library also real-world information artifacts are used to interact with the information system, similar to the Interactive Textbook and the Interactive Venn Diagram (Koike, Sato, Kobayashi, Tobita, & Kobayashi, 2000). This way the physical and the virtual (or digital) parts of an information object can be joined together. When for example a DVD is grabbed off the shelf and placed on a multitouch tabletop display additional information like the tagline of the movie, participating actors, user ratings or reviews can be displayed in a visualization that is virtually connected to the real-world object (see Figure 5).

Furthermore functionality like searching for semantic related information objects is bonded to the real-world objects providing users with a more natural and reality-based interaction. Other useful functions could include searching in the digitally available subtitles of a movie to directly jump to specific scenes in the movie or bringing full-text search to physical books. Also annotating and bookmarking becomes possible without harming the real book (Beck & Schrader, 2006).

Figure 5: The Blended Library Scenario – Real world media artifacts are used to access additional digital information and to define further search and filter criterions.

To search for related movies to the ones they already know, the students place DVDs on a digital tabletop information panel in the library (see Figure 5). With the visualization that is displayed around the physical media objects they are able to search for movies from the same directors or featuring the same actors. This gives them another way to semi-directed browse through the information space, giving them new ideas to refine their term paper topic.

3.2.3 Portals and Visualization

Portals (Perlin & Fox, 1993) provide a supplementary way of exploration. By selecting an arbitrary region of the information landscape via a bounding box, the user creates a portal providing a special view on the underlying information objects (see Figure 6). Portals can be seen as magic lenses (Bier, Stone, Pier, Buxton, & Derose, 1993) or visual filters. Moving and scaling them on the landscape enables the users to visually formulate complex queries in a highly visual and direct-manipulative manner (Ahlberg, Williamson, & Shneiderman, 1992). Using real portals (physical frames that are recognized by the computers behind a display) will further enhance the natural and reality-based interaction.

Within the portals of the Blended Library information system, multiple visualization techniques – for understanding, filtering and querying – are supported (see Figure 6). Examples of such visualizations are a rapid serial visual presentation (De Bruijn & Spence, 2000) (cover flow visualization), a scatter plot visualization called HyperScatter (Gerken, Demarmels, Dierdorf, & Reiterer, 2008) or a table-based visualization called HyperGrid (Jetter, Gerken, König, & Reiterer, 2005). Users are able to save portals for reference and later use, thus promoting executed search queries to actual digital objects on the information landscape.

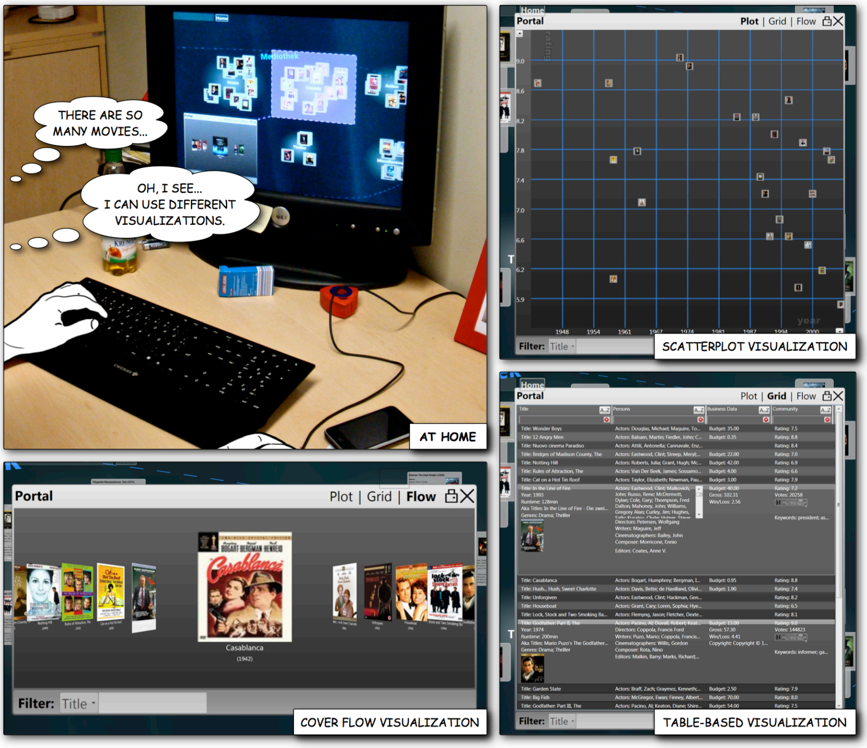

Figure 6: The Blended Library Scenario – Several analysis tools and visualizations are used to further investigate in a specific topic.

The students now know what they want to write about in the term paper. They create an outline and every member of the team gets a portion of the topic assigned for deeper analysis. In regularly held meetings they present the research they have carried out working at their home PCs and laptops using different visual analysis tools (see Figure 6).

3.2.4 Integration Into the Different Physical Contexts

Creative information work is a complex activity, usually executed in varying situations and environments. Therefore, one goal of the Blended Library is to develop an interface concept suitable for many different devices, which unifies all kinds of content and functionality with one consistent interaction model, while leaving the user the possibilities to establish own workflows, data structures or views on the information space. Due to the nature of zoomable user interfaces, the information presentation scales implicitly to a certain extent to different display sizes and is therefore applicable on very different hardware platforms, varying from small mobile devices (see Figure 7) over desktop PCs (see Figure 6) and TV screens (see Figure 8) up to large, high resolution displays (see Figure 4).

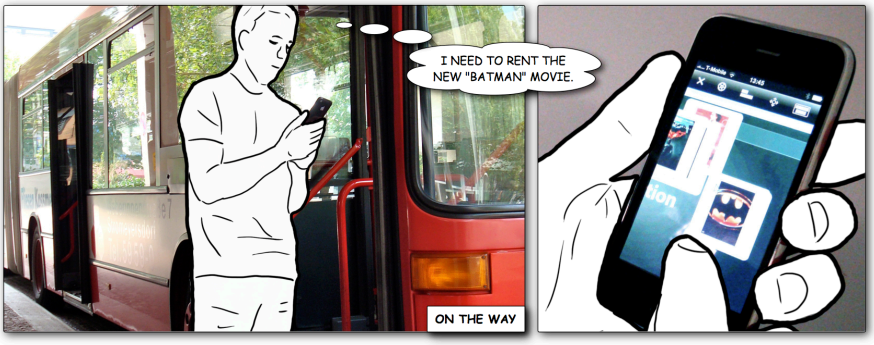

Figure 7: The Blended Library Scenario – The Blended Library information system is also accessible through mobile devices.

Also mobile access to the information system has become important (see Figure 7). On the way, the students are able to spontaneously jot down new ideas, access the digital media library or even watch a movie on a train ride, etc.

To make interaction with the Blended Library information system as natural and reality-based as possible a variety of different input devices is supported. Besides PCs and laptops, multitouch tabletops, wall displays and mobile devices, annotations written with real pens on real paper are digitalized on the go and immediately projected to the digital information landscape (see Figure 8). Anoto[7] technology is used to support this transfer of hand written notes into the digital information system.

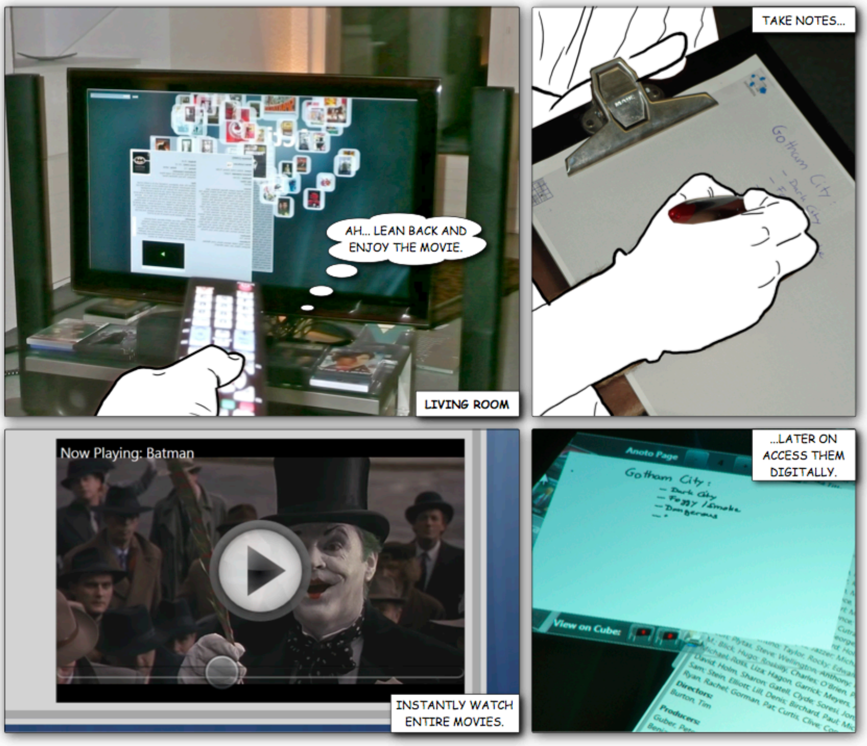

Figure 8: The Blended Library Scenario – On the home theater systems the movies are watched and notes are taken.

Since the seminar is about comic book adaptations in cinematics, obviously a lot of movie watching is involved in the knowledge work process. Such a task can best be carried out on the

[7] http://anoto.com – visited October 4, 2010

home theater system with the DVDs lent from the media library (see Figure 8). During a movie a lot of annotations are taken. The students later can directly access these annotations in digital form in the Blended Library information system.

3.3 Co-Located, Collaborative Information-Seeking

Another key concept of the Blended Library is the support for co-located, collaborative information-seeking and knowledge work. This important aspect of most information-seeking processes is particularly highlighted here and will later on be explained in detail by presenting the concept of the Search Tokens, the main contribution of this thesis.

Social interaction and social activities are important throughout most work processes in almost every domain of our life. Also in information-seeking and knowledge work there are a lot of tasks and activities where people are interacting with each other, as mentioned in chapter 2 – Theoretical Foundations. Kuhlthau for example introduces the concept of mediators as persons that will help knowledge workers during their information search process (Kuhlthau, 1993a). Mediators like librarians, tutors or co-workers are able to help people with technical and organizational problems during many tasks of information-seeking. Also, everyone of us has come into contact with situations where a collaborative effort had to be made to successfully carry out an information-seeking task (e.g. finding a location for the family vacation, deciding which movie to watch or finding the best recipe for a birthday cake).

The problem with today's information system however is that most of them are implemented as standard PC applications used with mouse and keyboard and designed for standard computer displays as output devices. These computer systems per se are optimized for single user interaction and thus hindering co-located collaboration efforts (Rogers, Lim, Hazlewood, & Marshall, 2009). The idea of the Blended Library acknowledges co-located collaboration as a key aspect in information-seeking and provides room to naturally address this issue, again using reality-based interaction techniques.

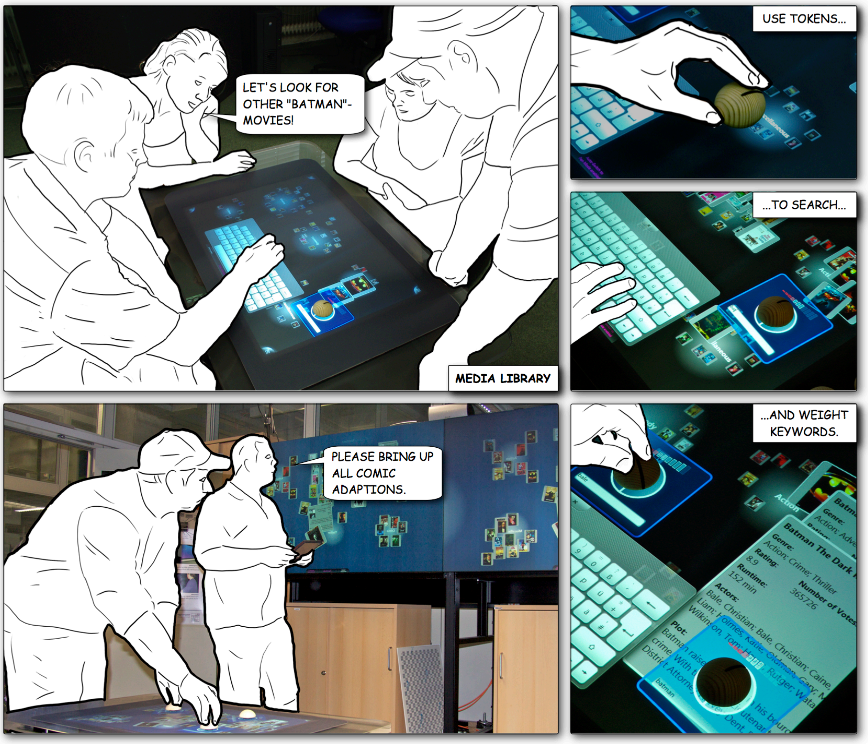

Figure 9: The Blended Library Scenario – To support co-located, collaborative information-seeking tasks multitouch tabletop displays and high-resolution wall displays are provided in the library.

> Regularly the students meet up to discuss their individual progress and find solutions for occurring problems. The library provides specially equipped work places for these team meetings (see Figure 9). Cubicles with large wall displays and multitouch tabletop displays are designed to best possible support the work in co-located, collaborative situations.

The vision of the Blended Library translates the high-level design goals of the blended interaction paradigm into more concrete concepts. By framing the context of this thesis (information-seeking and knowledge work in the library of the future) the more descriptive concepts of collaborative information-seeking, which are the main target of the defined research questions, can be designed and integrated into an overall user process as postulated by the blended interaction paradigm (see section 2.4 – The Blended Interaction Paradigm). Furthermore the research question (basic principles) is partially addressed by the concept of the Blended Library, which suggests using the ZOIL paradigm as visualization technique to provide consistent information presentation that scales over all contexts throughout the users knowledge work process.

Key Aspects and Conclusion

- To present the concepts of this thesis the context of the library is used as a natural environment for information-seeking activities.
- Based on the theoretical foundations from above the vision of the Blended Library combines the digital information space and information artifacts and facilities of the real-world library.
- The concept of the Blended Library uses several visualization and interaction techniques (information landscapes, semantic zooming, portals, divers visualizations, dynamic queries, blended interaction) to support users during the overall information-seeking process in different contexts (in the library, at home on the way, etc.) by supporting different hardware devices.
- As collaborative activities play a crucial role in knowledge work this thesis focuses on the aspects of collaboration in information-seeking.

4 Related Work

This chapter introduces the work related to the concept of the Search Tokens. It is divided into two parts: related work in the field of **collaborative information-seeking** and related work in the field of **tangible user interfaces for information-seeking.** The presented concepts are major sources of inspirations in the design process of the Search Tokens and help defining the overall goals and choosing the technologies to implement the concept. Therefore the systems and prototypes are also set into relation with the Search Tokens, which are introduced in chapter 5 – Concept of the Search Tokens.

4.1 Collaborative Information-Seeking and Knowledge Work

Collaboration in the field of information-seeking and knowledge work can be of diverse nature. Domain experts may be needed to help interpret certain information or hint at relevant information sources. Knowledge work experts like librarians and tutors may guide through the overall information-seeking process (Kuhlthau, 1993a). Often the workload has to be partitioned, simply because the amount of data involved is too big to handle by a single person. Size and complexity of datasets also call for domain experts from different disciplines and with different skill sets. These are some examples where collaboration is crucial to gain high quality results when analyzing, discussing and negotiating possible interpretations (Isenberg, Hinrichs, Hancock, & Carpendale, 2010).

4.1.1 Social Search

The term "social search" can be used in different meanings (e.g. search processes that involve collective intelligence, search that is based on the data of social network services or search activities making use of workspaces that enable social interaction). In co-located, collaborative information-seeking social aspects of search processes obviously are among the key aspects to consider. Evans and Chi provide an intentionally broad definition of social search including a range of possible social interactions during information-seeking:

> *"'Social search' is an umbrella term used to describe search acts that make use of social interactions with others. These interactions may be explicit or implicit, co-located or remote, synchronous or asynchronous."* (Evans & Chi, 2008)

Evans and Chi built this definition on the results of a survey on the searching behaviors on Amazon's Mechanical Turk[8] service (Evans & Chi, 2008). It is the attempt to formulate a definition of the term that canonically covers all meanings of "social search".

In the survey the authors were asking the participants about their searching behaviors before, during and after the actual search task on the information system, suggesting that all three points in time are relevant to social interaction. The survey investigated when, why and how social interaction occurred during the participant's information-seeking process.

- **Before search** – Pre-search activities like recognizing the need for information, initiating a search, defining search requirements or framing the search context can occur individually or in collaboration with others. Although these activities do not necessarily demand collaboration, nearly half of the participants exploited social interaction in this stage to advance their information-seeking process. By talking to friends, colleagues, clients, etc. they gained clarification and guidelines on the seeking task, got suggestions on where and how to find the information (e.g. URLs and search keywords) or were even looking for the actual answers inside of their social network.
- **During search** – Evans and Chi separate the actual seeking tasks into three types: Transactional search, navigational search and informational search (Broder, 2002). Transactional search (in the context of web search) involves navigating to a website to perform a certain transaction like downloading a file, finding driving directions or viewing the weather at the destination. Navigational search represents actions that are carried out to identify information from a familiar source (e.g. retrieving the URL for a certain website). For these two types of seeking tasks people did not socially interact a lot. However, in the tasks of informational search, which include information foraging

[8] http://www.mturk.com – visited October 4, 2010

(Pirolli & Card, 1999) and sense making (Pirolli & Card, 2005), a high demand for social input could be recognized through the answers of the survey.

- **After search** – Post-search activities mainly consist of organizing tasks (e.g. creating new documents to present or archive information for later reference) and distributing tasks (e.g. sharing newly gained information and knowledge with others). Again, the results of the survey suggest that social interaction plays a crucial role in the involved activities after the actual seeking tasks. People want to share their search results and get feedback and validation from colleagues and friends.

The provided definition also takes several properties of social interaction in information-seeking into account. Interaction may occur **co-located** (e.g. in an office environment or in a library) or **remote** (e.g. using the phone or other means of remote communication). Also social interaction may occur in a **synchronous** way (e.g. talking, chatting, etc.) or in an **asynchronous** way (e.g. using email, reading and writing public annotations and reviews, etc.). Furthermore, people may **explicitly** conduct social interaction (as in most examples above) or **implicitly**. The latter may for example occur when users can access tagging information that someone has used to organize personal bookmarks (as an example see the delicious social bookmarking platform[9]). Such information is not explicitly intended to be used by others. Overall, the results of the study by Evans and Chi show that collaboration and other forms of social interaction play an important part in the processes involved in information-seeking.

For the context of collaboration with digital information-seeking systems, this thesis suggests to add two more dimensions. A system may provide a **shared interface** (e.g. one computer display for the whole group of people to interact with) or **separate interfaces** for each user (e.g. multiple laptops or mobile devices for every person involved). Also a distinction should be made on whether a group's effort is to conjointly find and execute a **shared strategy** of information-seeking (involving negotiating on interaction – everybody knows what the others are doing) or simultaneously using **separate strategies** of information-seeking (involving multiple views on the

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[9] http://www.delicious.com – visited October 4, 2010

data – people use individual strategies and visualizations to contribute to the overall information-seeking process by providing solutions to sub-problems).

Another interesting aspects to look at are the means of collaboration that are used with a specific information system. Verbal communication, either spoken or written, may be the most obvious one, but also non-verbal communication like gesturing with arms and hands, pointing at interesting information, nodding or shaking the head may be important as well. Furthermore, facial expressions emphasizing agreement, disagreement, acceptance, disapproval, skepticism, etc. may or may not be facilitated by a certain information system.

The following sections are meant to introduce examples that implement different assortments of the characteristics of social search. Focusing on presenting examples for a wide range of these characteristics other interesting systems, like CoSearch (Amershi & Morris, 2008) and WeSearch (Morris, Lombardo, & Wigdor, 2010) in the context of collaborative web search, are not covered here. Section 4.3 – Conclusion of the Related Work will give an overview and categorization of the systems and prototypes described in this chapter.

4.1.2 Cerchiamo

Cerchiamo (Golovchinsky, Adcock, Pickens, Qvarfordt, & Back, 2008) is an exploratory search system that allows teams with a common goal to collaborate during information-seeking activities. The authors describe Cerchiamo as a synchronous and co-located information system but it could as well be used in a remote setting. The team members independently use dedicated search interfaces that route information, derived from each user through information retrieval algorithms, to the others to enhance their performance and the overall result quality. The idea is to allow users to execute different search strategies on separate interfaces, implicitly allowing them to influence and inform each other's interactions in real-time. Thereby, the users do not have to actively disengage from their current search activity. Underlying retrieval algorithms redistribute information and search suggestions, taking the different search strategies of the users into account.

The system architecture consists of three parts: the user interface layer, the regulator layer and the algorithmic layer (see Figure 10). The user interface layer of the implemented prototype system contains three different visualizations: an interface to execute text queries and browse search results (a user that uses this visualization is called a Prospector), a rapid serial visual presentation (De Bruijn & Spence, 2000) to make relevance judgments and review search result items (a user that uses this visualization is called a Miner) and a "shared display" containing information to the overall progress of the search process. Similar to the concept of the Blended Library (see section 3.2.3 – Portals and Visualization) these different visualizations allow for different search activities.

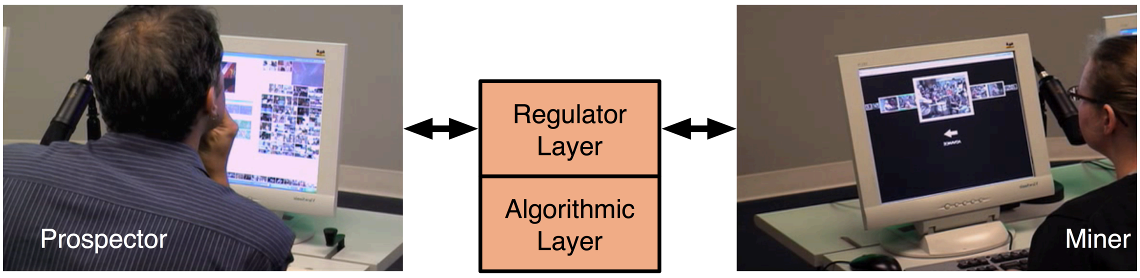

Figure 10: The user interface and a simplified diagram of Cerchiamo – The influences of the two different search roles Prospector and Miner are connected to each other through the regulator layer. Information retrieval algorithms in the algorithmic layer calculate the form of this bidirectional influence.

The Prospector is responsible to discover potentially promising directions of exploration. The Miner analyzes search result items to find information that was not initially obvious. The regulator layer manages the bidirectional influences between these two roles. The influence from the Prospector to the Miner has the form of retrieved, but unsighted documents that are stacked in the queue of the items the Miner will be looking at next. The algorithmic layer constantly reorders and reshapes the Miners queue of unsighted items by calculating real-time document rankings based on the ongoing information search activities of the involved information seekers. The system also identifies terms that are characteristic for documents that were judged as relevant by the Miner. These terms are made available to the Prospector for use in future queries and thus let influence also flow from the Miner to the Prospector.

The flow of influence in both directions happens without active effort of the users but through algorithmic mediation (Pickens, Golovchinsky, Shah, Qvarfordt, & Back, 2008). Cerchiamo shows how information retrieval algorithms can be used to facilitate collaboration in information-seeking. Collaboration happens automatically without active engagement of the involved users, which demonstrates a contrastive concept to the Search Tokens presented later in this thesis. There the users are elated to actively collaborate through different means of verbal and non-verbal communication and collective interaction to develop a conjoint search strategy.

4.1.3 DTLens

One of the earlier collaborative information exploration concepts using multitouch technology to enable synchronous, co-located group interaction with a shared interface is DTLens (Forlines & Shen, 2005). The system uses the DiamondTouch technology (Dietz & Leigh, 2001) to enable up to four people to access and explore geospatial data (see Figure 11). Thereby the system uses a focus+context (Cockburn, Karlson, & Bederson, 2008) approach to enable users to simultaneously work on one tabletop display but still use separate search and exploration strategies.

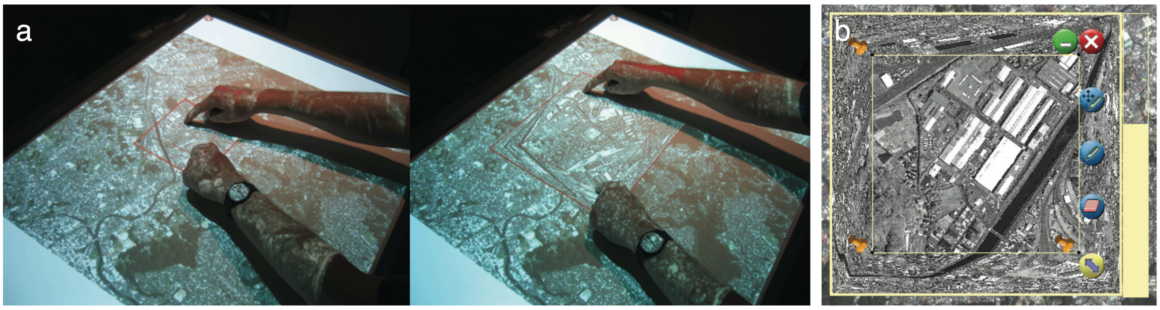

Figure 11: DTLens – A multitouch tabletop system to explore geospatial data in groups – images from (Forlines & Shen, 2005).

DTLens lets users define virtual lenses to select regions of interest by placing two fingers on the multitouch display (see Figure 11 – a). This lenses act similarly to the portals used in the Blended Library system (see section 3.2.3 – Portals and Visualization) but instead of providing users with alternative visualizations, geometrically zoom into the spatial landscape to reveal more detail information using a rubber sheet distortion technique (Sarkar, Snibbe, Tversky, & Reiss, 1993). By letting users access details on a delimited space of the display, the context of the visualized data is maintained for all others, thus allowing multiple users to simultaneously work on one and the same tabletop system. Additionally the lenses provide users with functionalities like annotating and saving of interesting regions (see Figure 11 – b).

Like in the concept of the Search Tokens, which will be introduced later in this thesis, the DTLens system uses zooming mechanisms to let users access detail information. But in contrast uses solely geometrical zooming and distortion techniques whereas the Search Tokens facilitate access to detail information by a semantic zooming approach (Perlin & Fox, 1993). Another difference between the two concepts is that the main goal of the DTLens system is to enable the simultaneous use of the display without hindering other users whereas the Search Tokens are meant to facilitate social interaction between the active users to conjointly work with the information system.

4.1.4 Cambiera

Following the idea of "brushing and linking" (Becker & Cleveland, 1987), a mechanism that connects multiple views on data by respectively reflecting selection and altering of information objects, Isenberg and Fisher define the term of "collaborative brushing and linking" as:

> *"...an awareness technique, in which the interactions of one collaborator on a visualization are visible to other collaborators viewing the data items in their own visualizations or views of the data."* (Isenberg & Fisher, 2009)

Collaborative brushing and linking allows people to individually carry out information-seeking activities, using separate seeking strategies, but still maintain a shared awareness of what others are contributing to the common goal.

With their example system Cambiera they show a tool for synchronous, co-located, collaborative information foraging in textual documents using a shared multitouch tabletop interface. Up to four people are able to simultaneously issue multiple search queries on the document base using four distinct on-screen keyboards. The search results are represented by an expandable result overview visualization where specific documents can be dragged out onto the shared display (see Figure 12 – a). To access the full-texts the document representations can be zoomed larger. The collaborative metadata that is implicitly shared through visual triggers consist of whether someone else has already issued the same search, another search has also found the document at hand and whether someone else has also considered or read the document at hand.

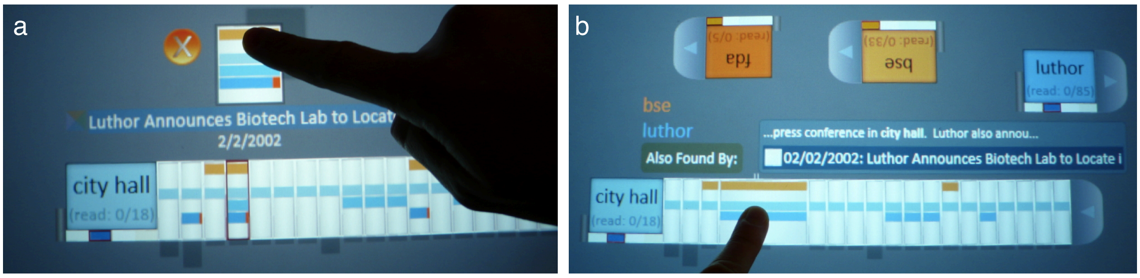

Figure 12: Cambiera – a) Expanded result overview for the query "city hall". A specific document that was also a match in three other searches is dragged onto the shared workspace for further review – b) Two different users (orange and blue) have each issued two different searches. The expanded result overview of the query "city hall" shows all result documents as white rectangles. The colored bars on the document representations indicate which other searches have also found the specific documents – images from (Isenberg & Fisher, 2009).

Each user is associated with a color (orange, blue, green, purple) and every search a user issues is associated with a different hue of this color, prominently represented in the result overview as background for the search term and other metadata (see Figure 12 – b). The documents in the expanded result view are represented by white rectangles. The colored bars reveal in which other searches the document was returned as a match, making users aware of other collaborators' common interests. Other color encodings and glyphs are used to establish the awareness whether specific documents were read by others and how often, thus indicating their importance to the collaborative information-seeking task.

Collaborative brushing and linking is also adopted in the concept of the Search Tokens. Different users and search queries will be represented by different colors to enhance the group's awareness of other collaborators' individual information-seeking efforts.

The examples introduced above cover most of the different characteristics of social search (co-located vs. remote, synchronous vs. asynchronous, explicit vs. implicit, shared interface vs. separate interfaces and shared strategy vs. separate strategies). Section 4.3 – Conclusion of the Related Work summarizes the systems again by means of these different characteristics.

4.2 Tangible User Interfaces for Information-Seeking

A well-known challenge in information-seeking and creative knowledge work is the users' urge of continuously adjusting parameters to refine search and filter queries or judge and decide on different options. Several studies in single user as well as collaborative settings, e.g. (Rogers, Lim, Hazlewood, & Marshall, 2009)(Swindells, Tory, & Dreezer, 2009)(Hornecker, Marshall, Dalton, & Rogers, 2008) have been carried out to compare different interaction concepts like classic mouse, pen-based, multitouch, and tangible user interface interaction. In this section two significant works are presented that provide important insights and ideas for the concept of the Search Tokens introduced later on.

4.2.1 Parameter Manipulation with Mouse, Pen and Physical Slider User Interfaces

Swindells et al. (Swindells, Tory, & Dreezer, 2009) state that when operating on digital systems, visual fixation on the user interface tools consumes much of the user's attention that then is lost for the primary task. This carries even more weight when working in a collaborative setting where along with the own tools the ones of other users have to be monitored to maintain awareness of the conjoint efforts. In their study the authors compare visual fixation (eye gaze within locations on the user interface) and performance for mouse, pen and tangible slider interfaces.

Users had to perform color-matching tasks manipulating a four-parameter color space (see Figure 13). The first parameter values ranged from black to white, the second parameter values ranged from green to magenta, third parameter values ranged from blue to yellow and the forth parameter values ranged from transparent to opaque. By altering the virtual or physical sliders respectively the users had to adapt the colored top and bottom segments to the constant segments on the left and the right (see Figure 13 – a). During the non-trivial tasks eye gaze fixations, task completion time and parameter distance travel was measured.

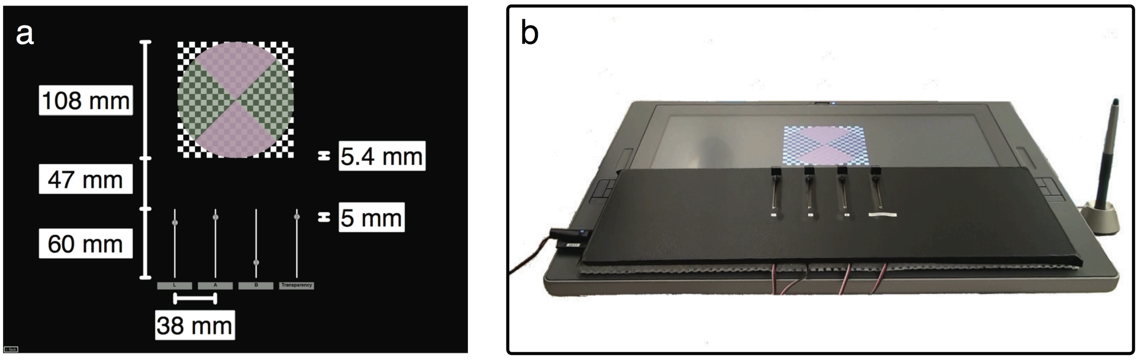

Figure 13: Color matching study – a) The color matching task display layout that was used for all conditions (mouse, pen and tangible slider) – b) The color matching task apparatus. The board with the physical sliders was removed for the mouse and the pen condition – images from (Swindells, Tory, & Dreezer, 2009).

The data from the eye gaze fixations was classified in fixations on the color target (where the two different colors had to be compared) and the user interface control region (where the virtual or tangible sliders reside). Overall the participants spent more time fixating on the color target than on the control region (256 fixations with the mouse condition, 274 fixations with the pen condition and 206 fixations with the tangible slider condition). This shows that fixations on the color target were slightly but not significantly less with the tangible slider interface compared with the two other conditions (mouse and pen). The same tendencies were observed when comparing the time spent handling the controls, the distances the individual slider controls traveled and also when comparing the overall performance of the participants only showing a small, non-significant advantage of the tangible slider user interface compared to the other two conditions. A major difference however could be observed comparing the eye gaze fixations on the control region (132 fixations with the mouse condition, 142 fixations with the pen condition and only 6 fixations with the tangible slider condition).

In conclusion the study showed that the tangible slider user interface in comparison to the graphical user interface elements controlled by mouse and pen interaction was able to drastically reduce visual attention (~90% less visual fixations) spent on the control tools and thus freeing this attention for other purposes like the actual main task and (translated to a collaborative setting) to the perception of other group members' interaction with a shared information system. The findings were taken into account when designing the concept of the physical Search Tokens for interacting with the Blended Library information system.

4.2.2 Tangible Query Interfaces

The prototypes presented in (Ullmer, Ishii, & Jacob, 2003) show two tangible user interfaces (Parameter Wheels and Parameter Bars) to formulate database queries using spatial arrangement of tokens to express Boolean combinations of multiple attributes and physical manipulation of tokens to modify parameter thresholds in real-time as proposed by the concept of "dynamic queries" (Ahlberg, Williamson, & Shneiderman, 1992). The prototypes build upon the ideas of the "Dynamic HomeFinder" (Williamson & Shneiderman, 1992).

Although the prototypes are not explicitly designed for collaborative work the authors state that the design goal was to leverage computers' capabilities for processing large amounts of digital information while preserving the benefits of tangible user interfaces such as strong physical and cognitive affordances, support for multi-handed interaction and co-located collaboration. In this sense the two interfaces can be characterized as supporting explicit, synchronous, co-located collaboration using a shared interface and supporting a shared strategy to carry out information-seeking activities.

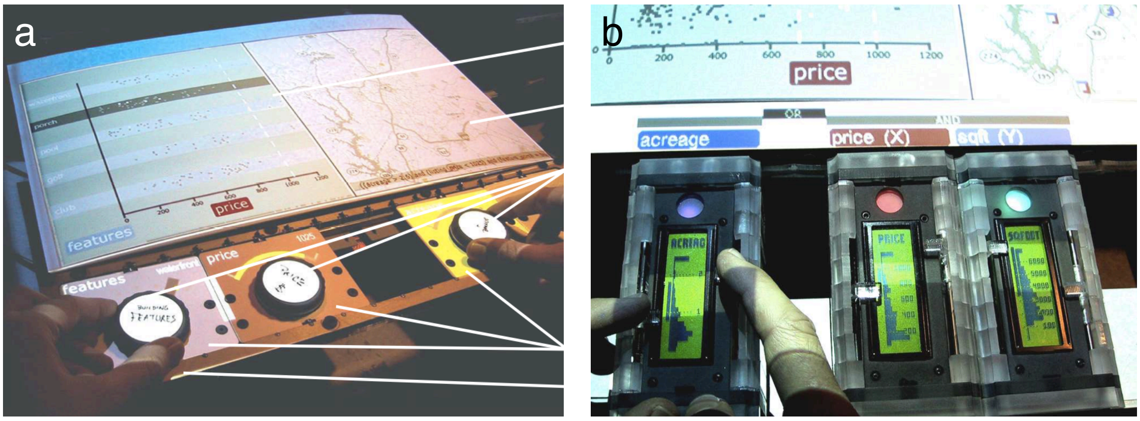

Figure 14: Tangible Query Interfaces: a) The Parameter Wheels placed in a rack at the bottom and the scatter plot and geographic visualization at the top of the interface – b) The Parameter Bars using the same visualization, spatially placed to formulate a Boolean query with an OR and an AND expression – images form (Ullmer, Ishii, & Jacob, 2003).

In the Parameter Wheels prototype (see Figure 14 – a) different parameter wheels, each representing another real estate database field (e.g. price, acreage, waterfront proximity, etc.) can be placed in a rack just below the visualization area of the prototype. The hard-labeled wheels placed on the left side of the rack are mapped to the x- and y-axis of a scatter plot visualization that is used to gain an analytical overview of the dataset. Turning the wheels will result in altering the parameters' thresholds and thus modify the set of data objects to be shown in the geographic map visualization on the right side. Besides the visualization area also the token rack is illuminated to augment the physical tokens with metadata like the selected value range of the current query. Exchanging one Parameter Wheel with another will change the scatter plot view substituting the attribute of an axis by the newly added one. On the right side of the rack additional Parameter Wheels can be added to the query.

In contrast to the hard-labeled Parameter Wheels, the Parameter Bars are embedded with an active display to indicate the attribute they represent and to show a value histogram of their assigned parameters (see Figure 14 – b). Thus it is possible to dynamically bind a new parameter to one of these tokens. The Parameter Bars prototype uses the same database and visualizations as before. Tow sliders on each Parameter Bar allow the user to modify both, upper and lower, bounds of the target parameter range. The spatial positioning of the bars in the token rack enables users to formulate Boolean expressions with the tokens. If two Parameter Bars are spatially separated a Boolean OR operation is applied between them, if they are placed adjacent a Boolean AND combines the two query parameters (see Figure 14 – b).

The authors describe their approach as "tokens+constraints". Tokens are interpreted as discrete, spatially reconfigurable physical objects that can hold digital information and operations. Constraints are confining regions where tokens can be placed within to propagate their meaning to the views on the data.

> *"Constraints are mapped to digital operations or properties that are applied to tokens placed within their confines."* (Ullmer, Ishii, & Jacob, 2003)

In their prototypes four different operations are associated with the placement of the tokens within the constraints of the query rack.

1. The physical presence of a token in the rack represents that the attribute and the parameter value of the token is now a part of the query.
2. The physical placement of a token in the rack leads to a view selection (different placement lead to different views).
3. Physical rotation (Parameter Wheels) and slider manipulation (Parameter Bars) represent parameter value selections.
4. Physical adjacencies of multiple tokens within the rack are translated to Boolean operations.

A lot of the concepts from these two tangible query interfaces like tokens based on rotation, dynamically binding of search parameters to physical tokens and the integration of Boolean operations through tangible user interfaces can be found in similar form in the concept of the Search Tokens as later described chapter 5 – Concept of the Search Tokens.

4.3 Conclusion of the Related Work

Besides other important work in the field of collaborative information-seeking and information-seeking using tangible user interfaces, the systems and prototypes presented in this chapter cover a wide range of the dimensions of social search and collaborative work defined earlier (see Figure 15). The classification of the systems and concepts is not entirely unambiguous. Most of them can act on both sides of one or more of the axes and it is left to personal interpretation and judgment how exactly they are classified. In addition it is important to mention that these dimensions are not meant to rank different concepts or to judge their quality. Different assignments ask for different implementations. Thus, choosing the right characteristics for the task at hand can help design better systems.

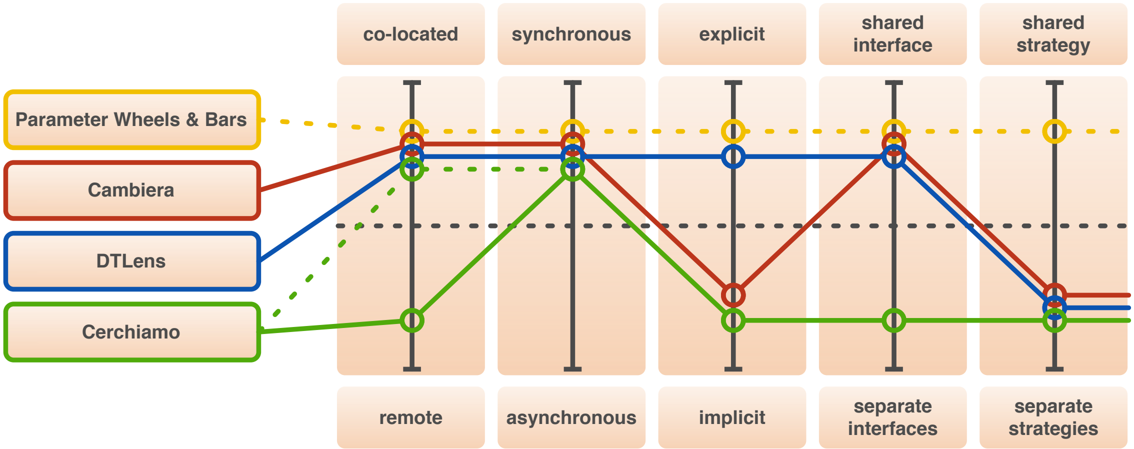

Figure 15: Classification of the related work into the different dimensions of social search and collaborative work.

One of the systems that is not easy to classify by this dimensions is Cerchiamo. The authors claim the system to be clearly co-located and explicit in terms of collaboration. This is probably due to the fact that the studies were carried out in a co-located setting. The system per se would also allow the collaborators to work remotely, which could be a major advantage of the concept. In a remote scenario implicit collaboration aspects would even more dominate the characteristics of the system.

As with every co-located system, which to a certain amount facilitates verbal communication and discussion between the users, also Cambiera and DTLens can be seen as explicitly supporting collaboration. The distinction that was made in this classification is based on the balancing of the importance of the implicit and explicit characteristics for the systems.

The two prototypes Parameter Wheels and Parameter Bars are added to Figure 15 although they were not explicitly designed as collaborative information systems. It is all the same interesting to see their possibilities and characteristics when being translated to this new context of collaborative information-seeking.

Not all characteristics of the classification are equally well covered by the selection of systems and prototypes in this chapter. No systems that use asynchronous collaboration were shown. Such systems however can be found in various situations of everyday's life. Some prominent examples are web forums, user comments on news articles or user reviews on products in online stores. But for the contributions of this thesis asynchronous collaboration does not play an overly important role.

Enabling collaborators to execute shared information-seeking strategies, another not so well covered characteristic, will on the other hand become an essential aspect in the Search Token concept presented later on. There are not many systems and prototypes that manage to cover this characteristic. Only a few claim to make some efforts in that direction, most of them simply by enabling verbal communication between the collaborators.

The prototypes for tangible user interfaces have shown different concepts that can enhance information-seeking activities by providing natural interaction techniques for manipulating query parameters. With respect to reality-based and embodied interaction such interfaces can help to better handle the complexity of many information-seeking activities.

Studies show that in contrast to mouse and pen based interaction tangible user interfaces can reduce the visual attention spent on the tools, freeing it for other purposes. This circumstance may be a big advantage in co-located, collaborative work settings where users, besides their own interaction with the information system, have to maintain awareness of what the other collaborators are doing. Through the tangible nature of these user interface elements they provide a high physical and visual affordance, enabling collaborative interaction between people that is not possible with today's standard user interfaces like PCs with mouse and keyboard.

For the research questions of the thesis, this related work has influenced the main goals of the new concepts for collaborative knowledge work by extracting a classification of different characteristics that can be selected to support specific information-seeking activities. But also many design ideas and practical interaction principles have been influenced by the presented prototypes.

5 Concept of the Search Tokens

The main contribution of this thesis is the concept of the Search Tokens. It presents an integrated part of the Blended Library providing users with a co-located, collaborative information-seeking interface. This chapter shows the design rationales behind the Search Tokens and how theoretical models and related work were applied to support the defined research questions (design goals, basic principles and realization). Basic interaction and visualization principles are formulated and then implemented in the Search Token prototype. After introducing the operation and handling of the Search Tokens with a short scenario the realization of the concept both the hardware and software part will be presented alongside with an explanation of the visual search and filter algorithms behind the Search Tokens.

5.1 Goals and Design Rationales

The concept of the Search Tokens provides mechanisms and tools to enable users of the Blended Library (see chapter 3 – Context of the Thesis) to carry out co-located, collaborative information-seeking activities. Figure 16 (a) shows the proposed work place for the Search Tokens with a picture of the Living Lab (Følstad, 2008) at the Human-Computer Interaction Group of the University of Konstanz. Key element of this work place is a multitouch tabletop display that acts as a remote control for the collaborative search activities. In (b) the Search Token user interface elements (physical tokens and the visualizations that represents their digital counterparts) are shown.

Figure 16: a) Living Lab of the Blended Library at the Human-Computer Interaction Group of the University of Konstanz – b) The Search Token interface.

In this section the design rationales behind the Search Tokens are introduced. These high-level design goals can be seen as requirements that are answered by the basic principles behind the Search Token concept as presented in section 5.2 – Basic Principles of the Search Token Concept.

5.1.1 Natural Collaboration

Collaboration in the Blended Library should be supported in a natural way in the sense of natural and reality-based interaction as proposed by (Jacob et al., 2008) as well as in the sense of how people naturally would collaborate with each other in a real world scenario (loosened for digital information systems) (Rogers, Lim, Hazlewood, & Marshall, 2009). Therefore, ways to integrate mechanisms of real-world collaboration have to be developed and implemented into the concept of the Search Tokens.

Also a physical setting where this co-located collaboration can take place has to be provided to the knowledge workers. The concept of the Search Tokens should addresses this issue by not reducing itself to a computer application for searching in digital data but by delivering an integrated concept of information-seeking in the Blended Library. In this case "integrated" does not only mean conceptually integrated into the users' work processes but also physically integrated into the facilities of the library.

The Search Tokens are not meant to be the only tool to be used during the users' information-seeking process as it is introduced with the theoretical models of information-seeking in section 2.3 – Supporting the Users' Work Processes. It is seen as an integrated part of the Blended Library that supports the users at the times where they rely on collaborative activities with colleagues, tutors, librarians, etc. to conduct their information work. Such activities may for example include the following:

- Collaborative browsing of the information space (e.g. by students to gain an overview of the context of an assignment)
- Presentation of success-proven strategies of knowledge work (e.g. by a tutor or librarian to guide a person or a group to successful paths of knowledge work)
- Collaborative generation of ideas (e.g. brainstorming to frame or outline a specific knowledge work assignment)
- Discussing and negotiating over possible alternatives (e.g. discuss alternative interpretation of information-seeking results)
- Presentation of individual findings and knowledge (e.g. present individual knowledge work efforts to other group members)

To support this kind of co-located, collaborative information-seeking, mechanisms to facilitate the visual awareness of what other collaborators are doing have to be integrated into the concept of the Search Tokens. An example for such mechanisms has been introduced in the related work with the concept of collaborative brushing and linking (Isenberg & Fisher, 2009) (see section 4.1.4 – Cambiera).

As for the supported information-seeking activities, the tool should support browsing oriented access to the information space as well as analytical methods to work with the data. The browsing oriented approach is meant to help users to gain an overview of the rather unknown content that is accessible with the information system. It has to be able to help generating new ideas, framing information needs, finding new information-seeking strategies on how to work with the information that is available to the users, etc.

As groundwork for technical discussions and a substantial understanding of the information-seeking problem at hand, comprehensive and complex analysis tasks have to be supported as well.

The provided mechanisms will help the group to advance the development of their knowledge in the field of the information-seeking assignment when using the system in the Blended Library.

5.1.2 Classification of the Search Token Concept

The main difference to most of the systems introduced in chapter 4 – Related Work is that the concept of the Search Tokens explicitly is designed to encourage the development and application of a **shared strategy** of information-seeking among the collaborators. The information-seeking activities it is designed for ask for that characteristic since these are activities where individual efforts, not connected to the development of the collective knowledge, cannot advance the information-seeking process of the group. Individual work efforts are important as well and have to be supported in the overall information-seeking process. But since they are out of the scope of the Search Token concept, other components of the Blended Library (e.g. individual PC-based and mobile interfaces) have to fill that gap.

One of the first systems to help facilitating natural remote collaboration by also including "informal communication" through the use of video transmission between two remote rooms was the VideoWindow System (Fish, Kraut, & Chalfonte, 1990). Since then there have been various efforts to provide remotely scattered groups of people with a more natural way of communicating and carrying out collaborative work. There are many examples where video transmission is used to achieve this goal (e.g. Skype[10], Windows Live Messenger[11], iChat[12], etc.). Another approach is to use virtual reality to let people from different locations meet in a virtual room (e.g. Second Life[13]). With the concept of the Search Tokens however, the design decision was made to use a **co-located** setting to provide the most natural collaboration possible. With this decision follows the use of **synchronous** collaboration techniques as well as the support for mainly **explicit** collaboration between the members of the participating group.

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[10] http://www.skype.com – visited October 4, 2010

[11] http://explore.live.com/windows-live-messenger – visited October 4, 2010

[12] http://www.apple.com/ichat – visited October 4, 2010

[13] http://secondlife.com – visited October 4, 2010

The design goal to lead users into finding and applying a shared strategy of information-seeking is also reinforced by using a **shared interface** for the concept of the Search Tokens. Through this decision the visual awareness of what other collaborators are doing is implicitly supported by the system since all collaborators are looking at the same view of the information. This collective awareness of the information-seeking process will additionally be enhanced by other technical mechanisms integrated into the Search Token concept (see section 5.2 – Basic Principles of the Search Token Concept).

Design Rationales behind the Collaborative Information-Seeking Concept of the Search Tokens

- Support co-located, synchronous, explicit collaboration using a shared interface to support shared information-seeking strategies.
- Allow for natural collaboration based on real-world conventions of social interaction.
- Provide a physical setting that is integrated in the Blended Library.
- Use natural, reality-based interaction techniques.
- Provide strong group awareness of the collective information-seeking activities.
- Support browsing oriented access to information.
- Support mechanisms for complex analysis of the information space.

5.2 Basic Principles of the Search Token Concept

This section introduces the technical mechanisms that enforce the high-level goals and design rationales from above in the concrete design of the Search Token interface. Figure 17 shows the nine basic principles that compose the core of the concept. The principles have emerged from related work and through the iterative design process that was applied during the development of the Search Tokens.

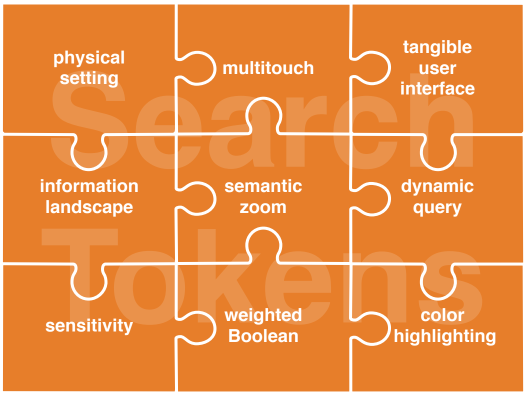

Figure 17: The basic principles that are applied to the Search Token concept.

The principles cannot be mapped one-to-one to the defined design goals. Therefore, they are divided by means of the technologies and concepts involved. The rather abstract description of these principles will be showcased more concretely in section 5.3 – Functional Description of the Search Token Concept.

5.2.1 Physical Setting and Work Environment

With the idea of the Blended Library the whole information-seeking and knowledge work process of the users is regarded as one large unit that has to be consistently supported from the beginning to the end. The concept of the Search Tokens fits into the spots where group collaboration activities are carried out. To integrate the concept into the Blended Library a physical workspace has to be defined. Since today's libraries are generally locations where users are expected to behave completely quiet to not disrupt the concentration of other visitors and collaborative group activities generally involve a lot of verbal communication it might seem to be appropriate to find another place for this purpose. Yet real-world libraries feature a lot of advantages in the context that is used to showcase the Search Tokens as described in section 3.1 – The Blended Library. Therefore, the creation of an infrastructure for co-located, collaborative work in form of cubicles inside the buildings of the library (see Figure 18) is proposed (Demarmels, Huber, & Heilig, 2010).

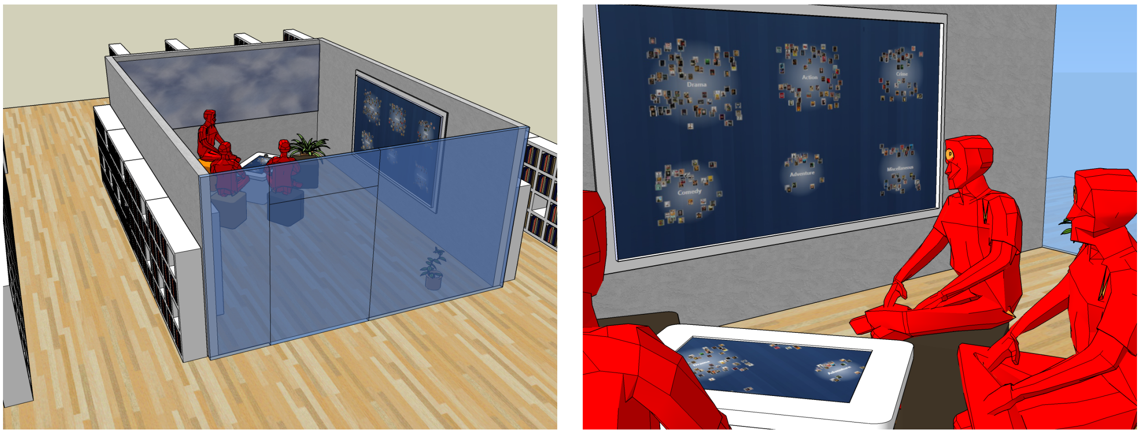

Figure 18: Workspace for co-located, collaborative activities in the Blended Library.

These cubicles are placed in central spots of the library building, holding space for groups of about two to six persons to carry out co-located, collaborative knowledge work. They enable a team to perform group activities like meetings, discussions and presentations without interfering the calm atmosphere that a lot of visitors of the library use for their individual knowledge work.

The cubicles are equipped with multiple displays. A multitouch tabletop display forms the control center for the knowledge work activities of the groups. Team members can place themselves near this tabletop display either sitting or standing around it depending on its physical design. The tabletop display is also the device that integrates the Search Token interface.

To improve the access to detail information of the digital information system an additional large, high-resolution wall display is proposed. On this display it is possible to represent more detail information at once (e.g. when comparing multiple information objects). The users are able to visually access the display from the tabletop or they can walk over to the wall display to take a closer look. The display can furthermore be used as an interactive, digital whiteboard as for example described in (Geyer, Jetter, Pfeil, & Reiterer, 2010). What information is shown on the wall display can be controlled from the tabletop, which acts as a remote control.

In addition to the 3D-scetches above, Figure 16 (a) shows the living lab at the Human-Computer Interaction Group of the University of Konstanz, where the concept of the Search Tokens is developed and evaluated. In the following the thesis will focus on the collaborative interaction with the tabletop display using the Search Tokens and leave out the interaction with the high-resolution wall display.

5.2.2 Multitouch and Tangible User Interface

The foundation of the Search Token concept is built upon a multitouch tabletop display that is capable of recognizing tangible user interface elements (the physical Search Tokens). Key benefit of the multitouch technology is that it allows people from all around the table to equally interact with the system. In contrast to information systems based on PC, keyboard and mouse interaction, a multitouch tabletop device democratizes the interaction with the system among all participating collaborators. This way the system is respecting the Search Token design goal of letting people develop and apply a shared strategy of information-seeking.

To further enhance the visual awareness of what other collaborators are doing with the system, the Search Tokens are based on the concept of tangible user interfaces (Ishii & Ullmer, 1997). The tokens enhance the visibility of interaction with the system since their physical appearance provides a higher visual and tangible affordance than a user interface that is solely based on digital sliders, text fields, buttons, etc. Through the use of physical tokens, multitouch tabletop technology and an object oriented user interface through the ZOIL paradigm (Jetter, König, Gerken, & Reiterer, 2008), the visual attention that is needed to operate the information-seeking tools themselves can be reduced as proposed by (Swindells, Tory, & Dreezer, 2009) (see section 4.2.1 – Parameter Manipulation with Mouse, Pen and Physical Slider User Interfaces).

Similar to the Parameter Bars (Ullmer, Ishii, & Jacob, 2003) (see section 4.2.2 – Tangible Query Interface) the Search Tokens can dynamically be configured with different search parameters (search keywords). Each token represents one distinct search criterion. Metadata on the specific search parameters are displayed in visualizations directly on the tabletop screen. These visualizations are virtually connected to the physical tokens, following their movement on the screen. Moving and turning the tokens makes the visualizations accessible to all participants around the tabletop display.

5.2.3 Visualization and Semantic Zooming

The Blended Library suggests a platform independent user interface to consistently access information on different devices (see section 3.2 – Key Concepts of the Blended Library Information System). The paradigm is based on the concepts of object-oriented user interfaces and semantic zooming (Perlin & Fox, 1993) to access details on demand. These concepts are technically implemented in the ZOIL software framework (Jetter, Gerken, Zöllner, & Reiterer, 2010), which is used to realize the Search Token prototype.

In addition the framework provides mechanisms to synchronize multiple display devices as different views on the same database. To integrate the Search Tokens into the Blended Library the concept uses the ZOIL framework also to connect the large, high-resolution display and the multitouch tabletop to access the data of the digital information system.

Figure 19: Search Token base visualization – An example of a base visualization that is used for the Search Token concept. The picture shows a dataset of about 300 movies clustered around the different genres they belong to.

The base visualization that is used for the Search Token concept is an information landscape that holds multiple information objects. The positions of these objects can be varied, giving the users different views on the data of the information system. In the context of this thesis the data consists of movie objects, as they would be found in a media library. Figure 19 shows (as one example of a base visualization) a dataset of about 300 movies that are clustered around their genres (Drama, Action, Crime, Comedy and Adventure) represented by the white halos. The information objects are represented by the movie poster and hold additional detail information like title, production year, budget and gross information, actors, producers, a plot summary, etc.

Through the fact that the underlying virtual information landscape is accessed by the users through zooming and panning interaction and has virtually infinite large boundaries, the amount of information objects that can be placed on the landscape is theoretically unlimited. Due to technical restrictions in hardware and software however (see section 5.4 – Realization of the Search Tokens), the amount of maximally supported data objects of the prototype lies in the range of 1'000 to 3'000 objects, depending on the complexity of the data structure of the information objects.

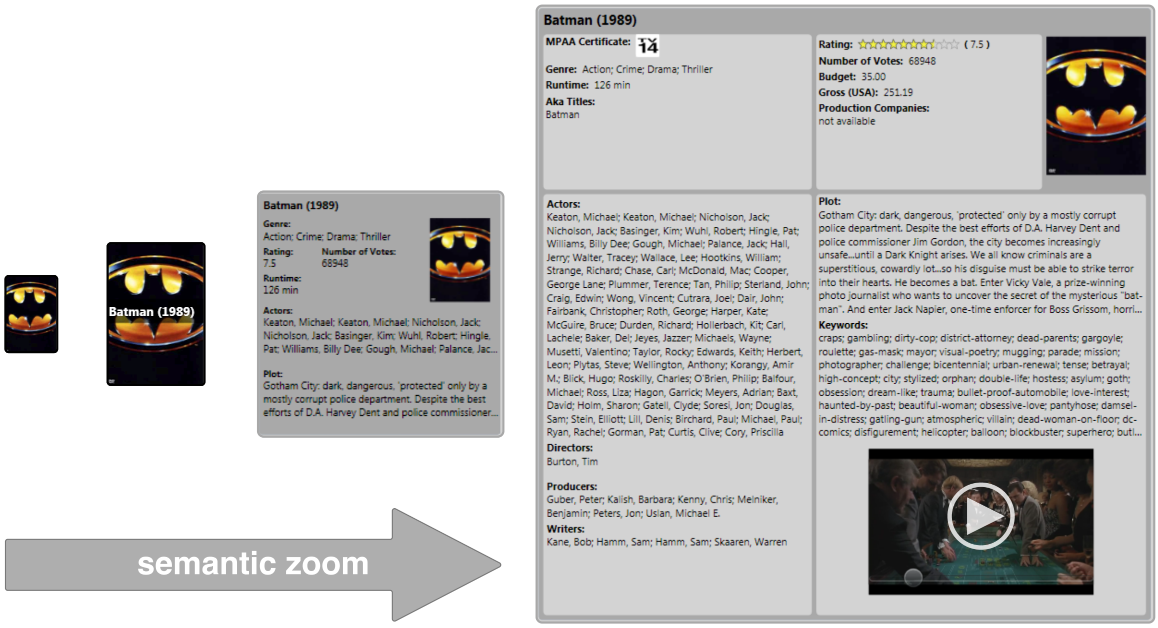

Figure 20: Semantic zoom of an information object in the Blended Library information system – The image shows the digital information object of the movie "Batman" in four different semantic zoom levels.

Information objects are displayed as virtual objects on an information landscape and can be zoomed larger to access more detail information. This is done by either zooming deeper into the landscape using two finger pinching gestures on the multitouch display or by zooming specific information objects larger, again using tow finger gestures on the virtual objects on the landscape.

Figure 20 shows how such an information object can be represented in different semantic zoom levels. The more space that is available to the object on the screen the more detail information is shown to the user (semantic zoom). Besides more detail information the objects also provides the user with more functionality, tying the objects and their functions together. In the last zoom level of Figure 20 (on the very right) the user can for example access the motion picture data of the movie object "Batman" through a video player function inside of the information object.

5.2.4 Dynamic Query and Sensitivity

The Search Token concept is based on dynamic filter mechanisms that bring interesting information objects to the users' attention using keyword-based dynamic queries (Ahlberg, Williamson, & Shneiderman, 1992). To support multiple users in their collaborative work in a co-located environment it is crucial that all the actions of the other group members can be followed and comprehended by everyone involved in the information-seeking process. Common strategies when filtering datasets in an information system hide all items that are irrelevant to the currently defined filter query. In a synchronous, collaborative setting however, this can cause confusion when different users simultaneously formulate multiple sub-queries. It may be confusing why in one moment an item was there and in the other it has disappeared because of a filter another user has defined. Such behavior cannot be traced back to the user's own interaction with the system.

To solve this problem a filter method inspired by the concept of sensitivity (Tweedie, Spence, Williams, & Bhogal, 1994) is used with the Search Tokens. To express that a certain information object matches a user defined filter criterion the visual representation of the matching objects is enlarged, emphasizing their importance to all collaborators. All information objects that do not match the filter query are not removed from the visible dataset, but are shifted into the background of the visualization. In section 5.3 – Functional Description of the Search Token Concept this mechanism is shown in action.

5.2.5 Weighted Boolean

The combination of multiple filter criterions is a fundamental concept to support co-located, collaborative information-seeking. It enables all collaborators to personally get involved in the search and exploration process. Therefore, the concept of the Search Tokens lets users combine multiple filter criterions using Boolean operations similar to the related work introduced in section 4.2.2 – Tangible Query Interface.

Following the concept of sensitivity described above, information objects that match more than one filter criterion are represented even bigger as the ones that only match a single filter criterion (see Figure 21). The default operation that is used to combine the different filter criterions, each represented trough a physical Search Token is a Boolean AND.

Figure 21: Two Search Tokens showing the concepts of sensitivity, weighted Booleans and color highlighting – The two movie objects in the center of the picture are larger than all other objects because they match one respectively two filter criterions defined by the yellow and the purple Search Token with the filter keywords "BATMAN" and "BALE". The keywords are highlighted in the detail information of the movie objects in the color of the corresponding Search Token.

Furthermore, the users can interactively alter the weight of every filter criterion. This can enhance the discussion in the way, that someone can scale the weight of a specific filter criterion up or down to better communicate the corresponding aspects to the other collaborators. It is also possible to define a rating for a result set by giving more important filter criterions of a complex query more weight than rather optional criterions. The information objects that match many of the important filter criterions get much bigger than the other objects.

The mathematical model behind the weighting of the filter criterions is based on the concept of weighted Booleans (Waller & Kraft, 1979). The higher a user defines the weight of a filter, the more influence it has on the resizing of relevant information objects. Additionally, weighted Boolean

NOT expressions can be formulated by filter weights converging to zero. All influences the different filters have on an information object are combined in its size on the information landscape. A more precise explanation of the filter algorithms will follow in section 5.5 – Algorithms Used with the Search Tokens.

5.2.6 Color Highlighting

The color highlighting mechanism of the Search Tokens visually links matching information objects with the corresponding filter criterions. Each token has a distinct color associated with itself. In the matching information objects the same color is used to highlight the matching keyword in the detail information of the object (see Figure 21).

Additionally the different colors in the result view of the information objects can be used to associate the important information objects with the user that is manipulating the corresponding Search Token as proposed with the concept of collaborative brushing and linking (Isenberg & Fisher, 2009) (see section 4.1.4 – Cambiera).

Key Aspects and Conclusion

- To enforce the goals and design rationales of the Search Token concept nine basic principles are introduced: physical setting, multitouch, tangible user interface, information landscape, semantic zoom, dynamic query, sensitivity, weighted Boolean and color highlighting.
- These principles form the fundamental visualization and interaction techniques the concept of the Search Tokens is built upon.

5.3 Functional Description of the Search Token Concept

This section introduces the concrete design of the Search Token concept. It shows how the nine basic principles explained above are implemented in a prototype to review and evaluate the concepts. Along with the detailed explanation of how the user interface is operated, a scenario gives a more practical view on the functioning of the Search Tokens.

5.3.1 Token and Visualization Design

The Search Token interface builds upon two main elements: physical tokens and their digital counterparts, visualizations that are virtually connected to these tokens (see Figure 22). In interplay with the tabletop display, each of these on-screen controls physically embodies a user-defined search term, enabling the users to interact collaboratively with the information system and allowing them to spatially organize multiple search terms on the table.

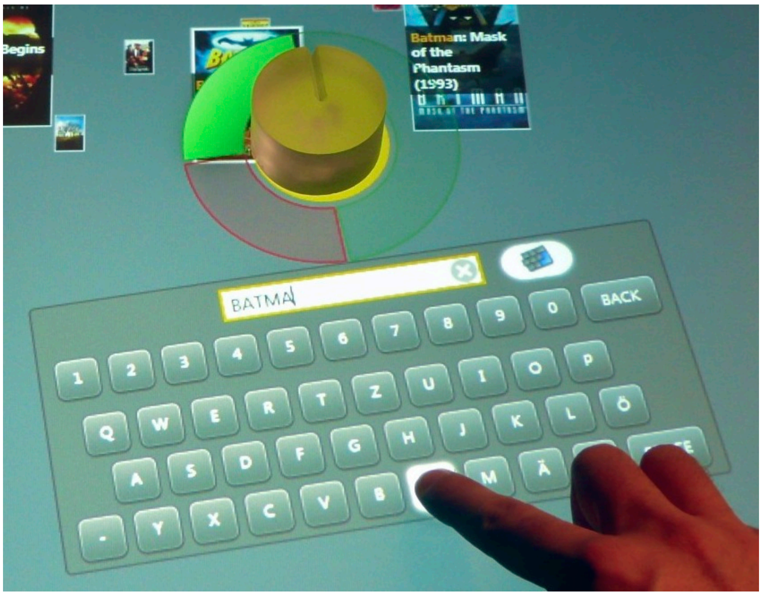

Figure 22: The Search Token Interface – When a Search Token is placed on the tabletop display a visualization that is virtually connected to the physical token appears. It consists of a text field that holds the filter keyword, an on-screen keyboard to enter the keyword and a circular indicator for the filter weight around the physical token.

When a Search Token is placed on the tabletop display the visualization appears. Turning and moving the token around on the display will also turn and move the visualization accordingly as if it would be attached (or glued) on to the bottom of the physical token. This way the search terms (embodied by the tokens) can easily be moved around the table and thus be accessed and altered by all people involved in the information-seeking process.

The visualization consists of three main parts: the textbox for the filter keywords, the virtual on-screen keyboard to input the search query and the indicator for the weight of the entered search term (see Figure 22). With the button next to the text field, the keyboard can be hidden to save screen space once the filter keyword has been defined. By lifting the Search Token off the tabletop display the visualization disappears and its filter is reset.

Scenario – In the scenario a group of students is interested in movies with the comic book character "Batman". They are working on the assignment to write a term paper together. As a team they intend to compare the distinct Batman movies that were produced in different decades. The students meet in the library and use one of the cubicle workspaces to conduct this work together. They are seated around the multitouch tabletop display, where the full content of the media library is available.

5.3.2 Formulating Filter Queries

Formulating a new search is straight forward with the Search Tokens. The textual keywords can simply be entered with the on-screen keyboard that appears when a token is placed on the multitouch tabletop display.

One student picks up a Search Token and places it on the tabletop display (see Figure 23). To initiate the first search, the student enters the term: "BATMAN" with the on-screen keyboard just below the token. With each key press the size of all movie objects on the information landscape that match the search term in one of their metadata attributes (e.g. title, actors, directors, plot keywords, etc.) increases, whereas the objects that fall out of the matching subset are brought to the background of the information landscape.

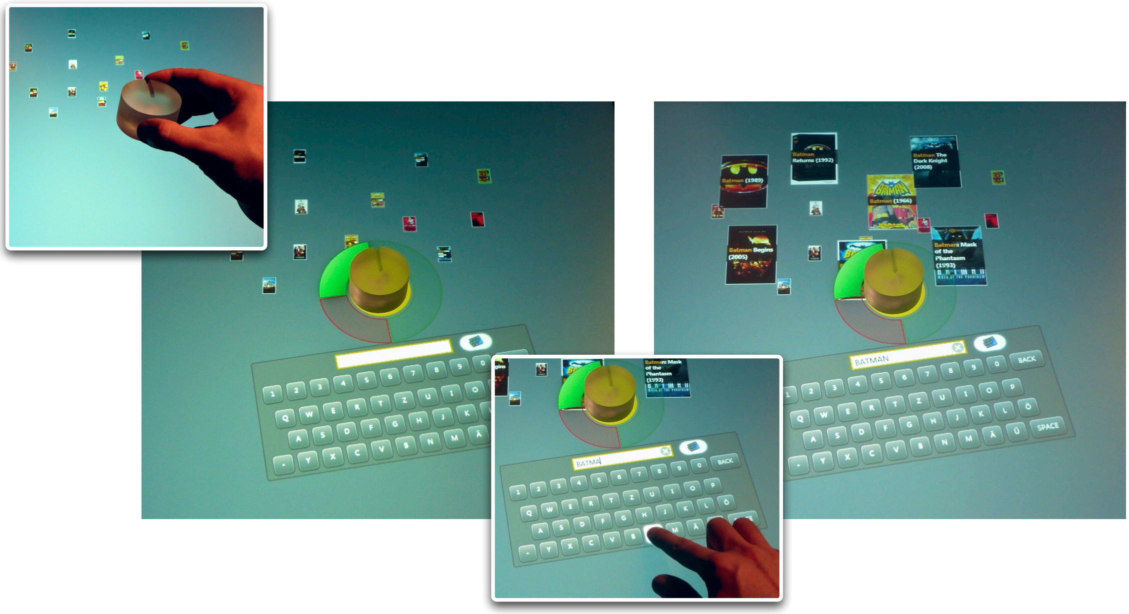

Figure 23: Defining a filter criterion – To define a filter using a Search Token, the user has to place a token on the tabletop display and enter the filter keyword (here "BATMAN") with the on-screen keyboard. The matching information objects will increase their size to attract the users' attention.

To facilitate the collaborative awareness of what is going on in the information system, the visualization of the dynamic query filters and their effects on the dataset is based on the concept of sensitivity (Tweedie, Spence, Williams, & Bhogal, 1994). The matching information objects are brought to the users attention by enlarging their visual appearance on the display (see Figure 23). In the example, by entering the keyword "BATMAN" all movies related to the comic book character Batman are enlarged on the virtual information landscape. Data objects that do not match the user defined filter criterion are not completely removed from the result set, but are brought to the background of the visualization. Through the step-by-step changes in the result view while typing in a keyword, these changes are traceable for all users looking at the information landscape on the tabletop display (see Figure 24).

Figure 24: Dynamic query – While entering a new filter keyword the result view is constantly updated.

In this example three steps of entering the keyword "BATMAN" into the Search Token filter are shown. In the first step (no text is entered yet) all movie objects are represented with their default size. In the second step ("BAT") nine movies are bigger than the others. In the third step ("BATMAN") only seven of the movie objects still match the filter.

The filter keywords of a Search Token can be altered at any time. This makes it possible to dynamically bind different search parameters to the physical tokens. In contrast to the Parameter Bars (see section 4.2.2 – Tangible Query Interfaces) the Search Tokens show all meta-information on the current filter criterion directly on the tabletop display and not on the token itself. This makes it possible to use simple lightweight tokens with no technical overhead. All the computing can be done by powerful dedicated computers that are hidden from the users.

5.3.3 Weighting of Filter Criterions

After a complete filter criterion is entered into the textbox a user can hide the Search Token's on-screen keyboard by pressing the button next to the text field (see Figure 25). Now the token acts like a turning knob. Inspired by the volume knob of a stereo or by a light dimmer, a Search Token can be turned to the right or left to increase or decrease the weight of its filter criterion. The value of the weight thereby can range from 0 to 2 (see Figure 26 a).

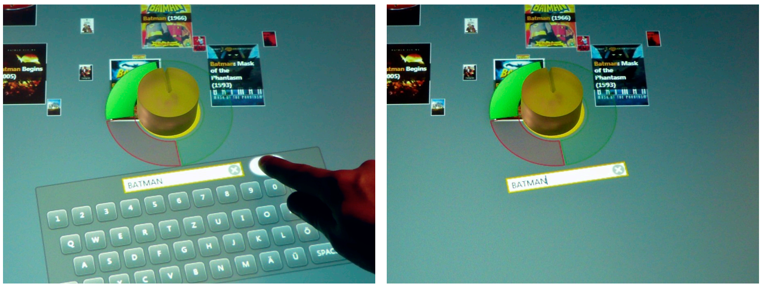

Figure 25: Hiding the keyboard after the filter criterion has been defined saves screen space. To enter a new keyword the user taps on the text field to activate the keyboard again.

Turning the knob to the right will increase the weight of a filter criterion and thereby the size of all matching movie objects, marking them as especially important to the current search (see Figure 26 b). Turning it to the left will decrease the size of the movie objects that match the filter (see Figure 26 c).

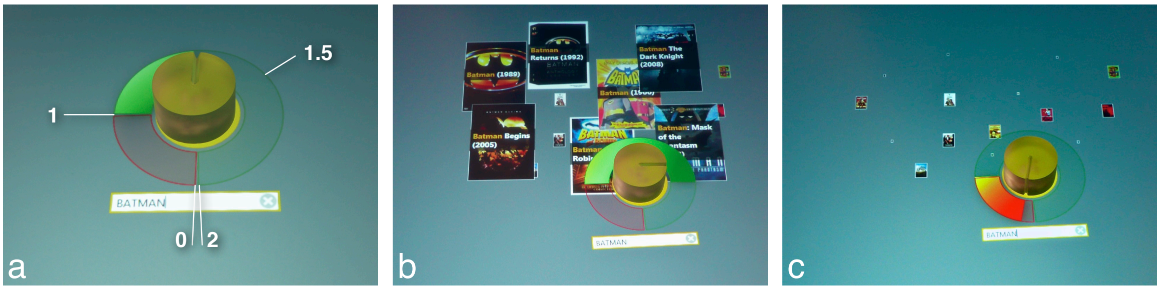

Figure 26: Weighting of a filter criterion – By turning the Search Token to the right and to the left, the weight of the filter is increased and decreased. a) The value ranges from 0 to 1 (red weight indicator part) and from 1 to 2 (green weight indicator part). The effect of altering the filter weight is that matching information objects will either increase their size (b) or decrease their size (c).

After the whole search term is entered, all movies related to "BATMAN" are highlighted to the group sitting around the display. The student now hides the on-screen keyboard. By turning the Search Token to the right the matching movies get even larger and more detail information is becoming visible.

Luminescent circlet sections around the token indicate the current weight factor of the Search Token. In the case of a weight above 1 (the filter increases the matching information objects' size) the indicator is glowing in bright green, in case of a weight below 1 (the filter decreases the matching information objects' size) the indicator is glowing red (see Figure 26).

By turning the knob to the fare left, the weight of the filter criterion will decrease below 1, and thus shrink the matching objects to a size smaller than their default size. This way a user is able to formulate filter criterions that correspond to a weighted Boolean 'NOT' and thus temporarily put certain objects that are not of interest into the background of the information landscape. In the related work (section 4.2.2 – Tangible Query Interfaces) the rotation of circular tokens was used in a similar manner to alter parameters of dynamic queries.

5.3.4 Combining Multiple Sub-Queries

To formulate more elaborate search queries multiple Search Tokens can be placed on the tabletop display. By combining these sub-queries with weighted Boolean AND operators, complex filter criterions can be formulated collaboratively by a group of knowledge workers. All sub-queries, each represented by one Search Token, are combined in the conjoint result view (see Figure 27).

As next step, the students try to separate the two newest Batman-movies from the ones produced in the 1990s and late 1980s. Although they do not know the exact release dates of the movies, one student has an idea how to achieve this goal (see Figure 27). He recognizes the poster of the latest Batman-movie "The Dark Knight" and zooms into its detail information using a two finger pinching gesture. The detail information reveals that "Christian Bale" has played the character "Batman" in this movie. The student zooms out to overview the whole data set and picks up another search token to define the search term "BALE". The two filter criterions "BATMAN" and "BALE" are combined by a weighted Boolean AND, so that the two newest Batman-movies (with "Christian Bale" as "Batman") become even larger then the other Batman-movies.

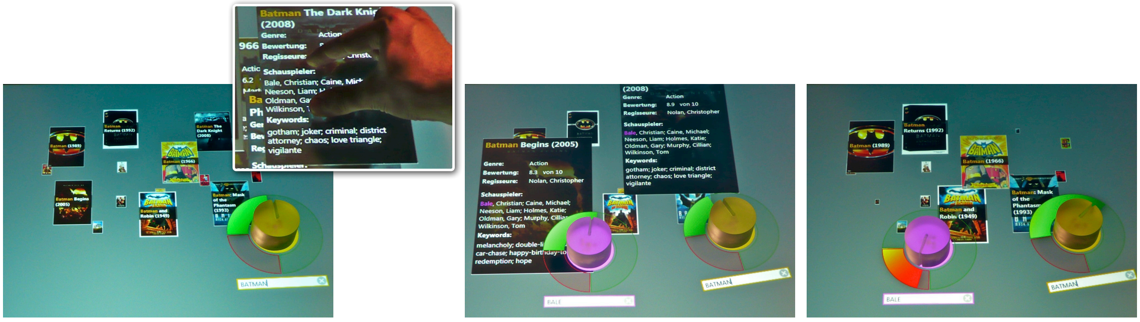

Figure 27: Multiple Search Tokens to formulate complex weighted Boolean queries – Multiple filters will be combined by weighted Boolean AND (here "BATMAN" AND "BALE"). The image shows the effects that different weighting of the Search Token filters has on the result set.

The students use this mechanism to consecutively increase and decrease the size of the newer and older Batman-movies and thus visually separate them from each other. The filter keywords of the two Search Tokens are highlighted in the detail information of the matching movie objects in the same color as the corresponding tokens. This helps to visually connect the filters with the resulting information objects and with the people that are handling the Search Tokens.

To further improve the access of the detail information of specific movie objects, the students transfer several objects to the high-resolution wall display. On this display they have more screen space to compare multiple movies and write annotations for further use.

To remove a filter the Search Token simply can be removed from the table. When it is placed back on the table the filter will be restored again. To replace a filter with a new keyword the user can either use the backspace key of the keyboard or the x-symbol on the right side of the text field to delete the current keyword. When the on-screen keyboard has been hidden using the button on the right of the text field, a tap on the text field will fade it back in.

5.4 Realization of the Search Tokens

This section describes the development process of the Search Tokens. It shows what technologies are used to implement the concept prototype and how the design of the Search Tokens evolved on the hardware and the software side.

5.4.1 Hardware and Software Technologies

To realize the concept of the Search Tokens a Microsoft Surface[14] unit is utilized as central multitouch tabletop display. The unit uses rear projection and infrared image recognition to recognize different object types like fingers or tagged, physical items. The system has the form factor of a coffee table inside of which the whole technical equipment is placed.

Figure 28 a) shows a schematic plan of the unit. The diffuser (1) is where the picture of the video projector (4) becomes visible to the users. The infrared LED light source (2) emits light from the bottom of the table through the diffuser. If a finger or any object that reflects infrared light is placed on the table, multiple infrared cameras inside of the unit will capture the reflected light. The computer (3), which is also inside of the tabletop's body, will translate these reflections into appropriate events that can then be handled by the software.

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[14] http://www.microsoft.com/surface – visited October 4, 2010

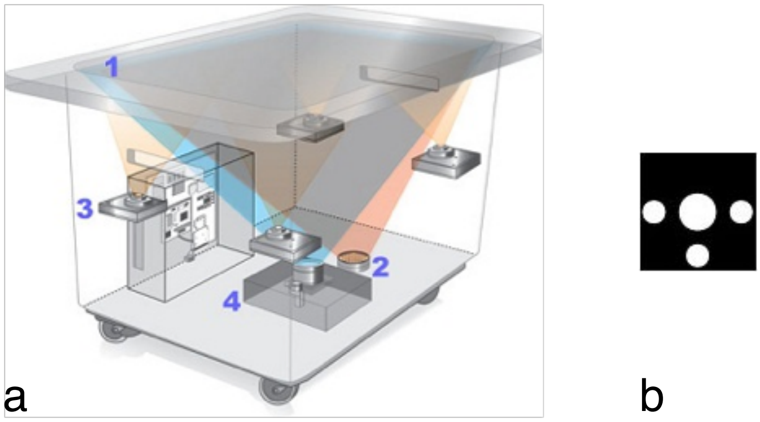

Figure 28: a) Schematic plan of a Microsoft Surface unit – 1) screen (diffuser) – 2) infrared LED light source picked up by multiple infrared cameras (net resolution of 1280*960 pixels) – 3) computer (Core 2 Duo processor 2.13 GHz, 2GB of RAM and a 256MB graphics card with Windows Vista as operating system) – 4) projector (1024*768 pixels) – b) Objects that are tagged with similar "Byte Tags" can be recognized and identified by the Microsoft Surface unit.

To recognize physical objects that are placed on the surface of the tabletop display, so called "Byte Tags" (see Figure 28 b) have to be attached to the objects. Through the dot pattern on the Byte Tags the system is able to recognize the objects' exact position and orientation. This enables for example the Search Token visualization to be virtually connected to the physical token.

The Search Token prototype is implemented with the .NET framework and WPF. The code is written in C# and XAML. For the multitouch and token recognition the Microsoft Surface SDK is used. For some core visualization techniques (e.g. semantic zooming and multiple display synchronization) the ZOIL software framework (Jetter, Gerken, Zöllner, & Reiterer, 2010) is used.

5.4.2 Evolution of the Search Token Design

The Search Tokens are meant to be a tool to enhance information-seeking in co-located, collaborative environments. Originally, the pragmatic design goals were to provide good visibility of the tool, simple and natural handling with an easy way to dynamically alter the search parameters of the dynamic queries in the Blended Library information system. During the elaboration process of the concept several versions of the Search Tokens evolved.

The first version of the Search Tokens was implemented very rudimentary, more as a proof of concept. The tokens were put together of soda caps and fridge magnets, covered with paper to paint the filter weight indicator on with a marker (see Figure 29). To enhance the handling and the feel of these tokens the caps were filled with coins to increase their weight.

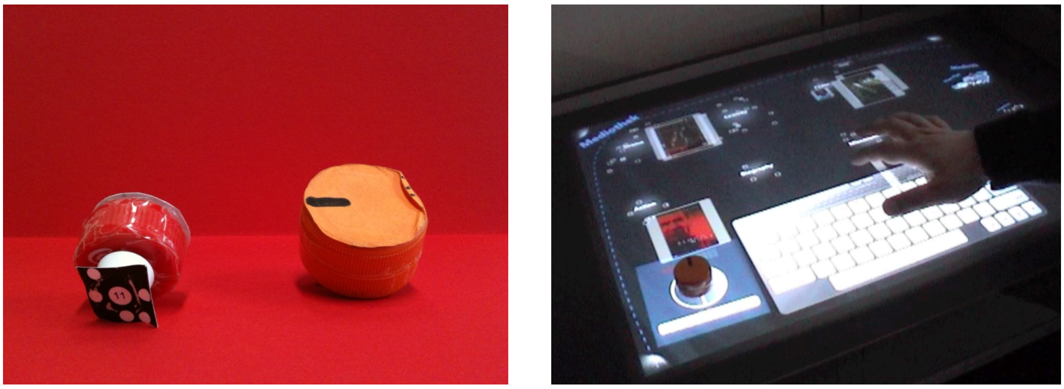

Figure 29: 1st generation Search Tokens – Made out of soda caps, fridge magnets and paper. The Byte Tags are affixed on the bottom.

The digital user interface consisted of the same main elements as the latest version of the Search Tokens: a text field for the filter keyword, a weight indicator (see also Figure 30) and an on-screen keyboard. In contrast to the latest version of the Search Tokens (see chapter 5 – Concept of the Search Tokens) the weight indicator was on the top of the visualization consisting of small bars (red for weights below 1 and blue for weights above 1). The keyboard was not bound to the Search Tokens. The users had to share one on-screen keyboard to enter filter keywords into the different text fields.

Figure 30: 2nd generation Search Tokens – Made out of wooden hemispheres. The Byte Tags are affixed on the bottom, which is blackened for a better detection of the tags by the tracking system.

In the second version of the Search Tokens the design was more elaborate. The tokens were made out of wooden hemispheres, giving the users a comfortable feeling when interacting with them. The Byte Tags were glued onto the bottom of the tokens as in the first version. The weight indicator was graved into the wood.

The people that used the wooden tokens generally found them to be a little bit old-fashioned. Therefore the third version of the Search Tokens was built of plexiglass, which was perceived as very pleasing by most users (see Figure 31). The Byte Tags were drilled directly into the token body and filled with infrared reflecting dye. The surfaces of the tokens were roughened so that the light from the display screen below was dispersed on the physical token. This way the different Search Tokens on the tabletop could distinctively be colored, which was later used to highlight the different filters on the screen. The tokens gained additional visibility as they were now "actively" emitting light.

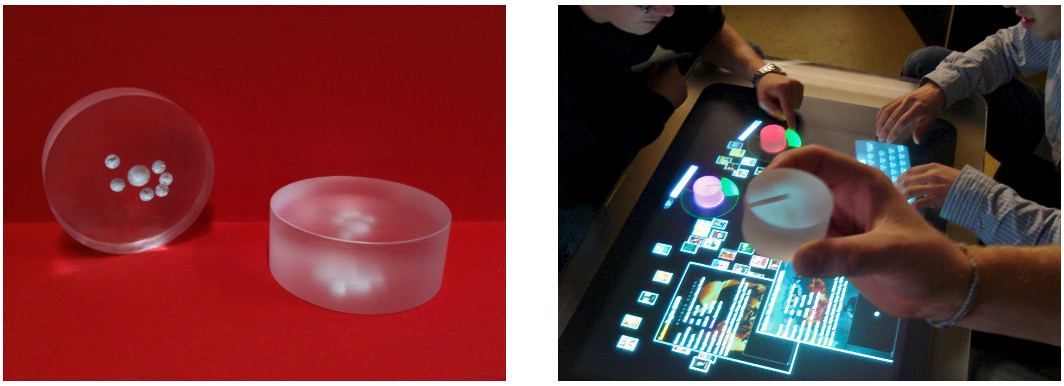

Figure 31: 3rd generation Search Tokens – Built with plexiglass cylinders. The Byte Tag pattern is drilled into the plexiglass body and filled with infrared reflecting dye.

A major problem with the new material was the bad detection of the Byte Tag patterns. When the users grabbed the tokens, their hands were interfering with the tags because of the see-through plexiglass. To overcome this problem, the latest version of the Search Tokens feature an infrared cut filter at the bottom of the tokens (see Figure 32). This filter foil cuts the infrared light and only reflects the Byte Tag pattern back to the cameras inside of the tabletop unit, still passing the visible light of the display to the surface of the plexiglass tokens.

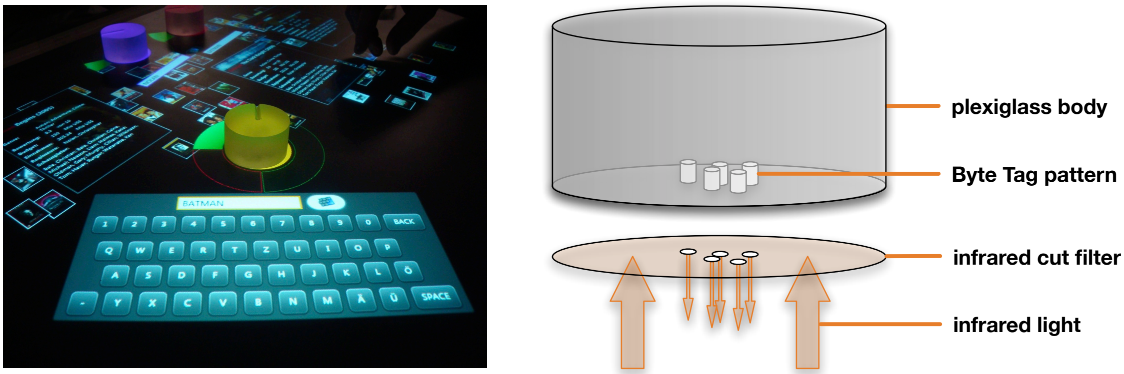

Figure 32: 4th generation Search Tokens – For optimal detection and elimination of interference factors an infrared cut filter foil covers the areas where no dye was added to the token.

Along with the physical evolution of the tokens, also the Search Token visualization evolved. Besides the color highlighting also the filter weight indicator changed from the bar visualization to the red and green circle segments as described in section 5.3 – Functional Description of the Search Token Concept. The graved indicator on the physical tokens is now mapped one-to-one to the digital indicator of the visualization. Furthermore every token now has its own on-screen keyboard enabling multiple users to simultaneously define new filter criterions.

5.5 Algorithms Used with the Search Tokens

In this section some essential algorithms and code fragments of the Search Token concept will be presented. For reasons of better understandability of the basic principles, the algorithms and code snippets are slightly simplified.

5.5.1 Managing Multiple Search Token Filters

The Search Tokens enable the formulation of weighted Boolean filter queries. Each Search Token thereby represents one filter criterion or filter keyword and a corresponding weight. The keywords can at any time be altered through the on-screen keyboard. The weight of the filter can be altered through manipulation of the token orientation on the tabletop display. As more than one filter may be a match on an information object, the influence of all filters has to be combined at runtime. Therefore, every time a user alters one of the filters, by either altering the keyword or by increasing or decreasing its weight, all information objects on the information landscape have to be recalculated and redrawn. This is necessary because through the altered filter:

- More information objects could be falling into the matching subset of the current query.
- Some information objects could now not be in the matching subset anymore.
- The screen size of the matching information objects could be different than it was before.

To manage all filters the *FilterManager* class is introduced (see Figure 33). It manages all active filters (Search Tokens that are placed on the tabletop display) and the calculation of the size of every information object according to all matching filters.

The class follows the singleton design pattern. Only one instance of a *FilterManager* is needed by the system. Therefore the static *get* method will call the constructor and create the singleton instance of the class on its first call. After that this method will return a reference to the only instance of the class every time it is called.

```
class FilterManager
{
   // singleton instance
   private static FilterManager instance;
   // list with all active filters
   private List<Filter> Filters;
   // the information objects that can be filtered in the system
   public Movie[] Movs;
   // visual properties of the information objects
   // that are cached to enhance performance
   public IVisualProperties[] VProps;
   public double[] Widths;
   public double[] Heights;

   // the constructor of the FilterManager -
   // it can only be called by the get()-method
   private FilterManager(){
      filters = new List<Filter>();
      // get all information objects into the FilterManager data structure
      var rc = Database.getInstance().ObjectCache.OfType<RootCollection>().First();
      Movs = rc.OfType<Movie>().ToArray();
      // initiate the default values for the cached properties
      VProps = new IVisualProperties[Movs.Count()];
      Widths = new double[Movs.Count()];
      Heights = new double[Movs.Count()];
      for (int i = 0; i < Movs.Count(); i++){
         VProps[i] = rc.GetVisualProperties(Movs[i].ID).First();
         Widths[i] = VProps[i].Width;
         Heights[i] = VProps[i].Height;
      }
   }
   // get the singleton instance of the FilterManager class
   public static FilterManager get(){
      if (instance == null)
         instance = new FilterManager();
      return instance;
   }
   // add a new filter to the FilterManager
   public void addFilter(Filter f){
      Filters.Add(f);
   }
   // remove a filter from the FilterManager
   public void removeFilter(Filter f){
      Filters.Remove(f);
   }
   // perform all calculations after a filter has been altered
   public void filterNow(Filter focusedFilter){ ... }
   // reset all information objects
   private void resetObjectsSize(){ ... }
   // resize one specific information object on the information landscape
   private void resizeObjectOnLandscape(IVisualProperties vp, double w, double h){ ... }
}
```

Figure 33: Code snippet – FilterManager class.

In the constructor a list called *Filters* that holds all filters (Search Tokens) that later will be added is instantiated. Then all information Objects (here of type *Movie)* will be saved into the internal data structure (the array *Movs).* In parallel, the visual properties of these information objects will for performance reasons be saved in the arrays *VProps, Widths* and *Heights.*

Besides the *get* method, two other methods are public and can be called from outside the class itself: the *addFilter* and the *removeFilter* method. Every time a new Search Token is placed on the tabletop display, the *addFilter* method will add the new filter to the list in the *FilterManager*. Accordingly, the *removeFilter* method will be called when a Search Token is removed from the tabletop display.

The last public method is called *filterNow*. Every time a user alters the keyword of a filter or changes its weight, this filter will call the *filterNow* method. In there, first the visual properties of all information objects will be reset to the default values with a call of the *resetObjectsSize* method. Then, by iterating over all information objects *(Movs)* and all filters (Filters), the new sizes of the information objects will be calculated and the objects will be redrawn on the display (see section 5.5.2 – Information Object Resize Algorithm).

The method *resizeObjectOnLandscape* will be called after every information object has its new visual properties. It calculates the new position according to the new width and height and then implicitly forces a repaint of each object by writing the cached visual properties into the system properties.

5.5.2 Information Object Resize Algorithm

The resize algorithm of the Search Tokens is based on a simple mechanism. Each filter consists of a keyword and a weight. The keyword can either match a specific information object (this is the case when the keyword is found in the metadata of this information object) or not match (when it is not found in the object's metadata). The weight of each filter can be between 0 and 2 and corresponds to the resize factor this filter will add to the size of a matching information object. Therefore a weight between 0 and 1 will shrink all matching information objects, which corresponds to a (weighted) Boolean NOT operator. A weight between 1 and 2 will increase the size of all matching information objects. For example, a filter that matches a specific information object and has a weight of 0.1, would shrink this object to a tenth of its size, where as a weight of 1.6 would increase its size by 60 per cent.

The real size of an information object is calculated of all weights of every matching filter. For example if three different filters match a specific information object, one with a weight of 2, one with a weight of 1.5 and one with a weight of 0.8, the size of this object will be 2.4 times (2 * 1.5 * 0.8 = 2.4) of its default size.

This simple algorithm is modified to counteract to three different problems that will be explained in the following subsections:

- Short keywords should not lead to clutter by getting a large number of information objects too big.
- Information objects that match a filter should get bigger even with low weights, so that more detail information can be shown early through semantic zooming.
- Once all detail information of an object is visible, the growth of this object should be damped so that it does not cover too much screen space.

Short Keywords – While entering a filter criterion the Search Tokens act like a dynamic query interface. The result of the filter will be altered with every key press. Therefore it is often the case that temporarily short keywords are defined (one, two or three letters), for example when starting to enter any new keyword. Such short keywords will generally match a large number of information objects, which will cause all of this objects to get bigger. This effect can lead to unnecessary clutter because only a few of these information objects in the end will be of interest for the users. Therefore, the filter algorithm scales the weights of filters with very short keywords down (see Figure 34).

```
// weaken short keywords
if (filter.keyword.Length >= 4)
   resizeFactor *= filter.weight;
else
   resizeFactor *= Math.Pow(filter.weight, 1/(double)(5-filter.keyword.Length));
```

Figure 34: Code snippet – Short keywords.

If a filter criterion has less than 4 letters, the factor that is added to the cumulated resize factor of all active filters is scaled down by taking the (5 minus keyword length)-th root of the filter's weight instead of the full weight.

Keyword	Keyword Length	Filter Weight	Resize Factor
"B"	1	2	1.19
"BA"	2	2	1.26
"BAT"	3	2	1.41
"BATM"	4	2	2
"BATMA"	5	2	2
"BATMAN"	6	2	2

Table 2: While defining a new filter criterion (here with the keyword "BATMAN" and a filter weight of 2) the matching information objects will not be resized by the full weight factor (2) until the keyword has reached a length of at least four letters.

The table shows as an example how the resize factor of the filter will automatically be scaled down while typing the first three letters, when defining a new filter ("BATMAN"). The full weight of the filter will not be used until the keyword reaches a length of four or more letters.

Pushing the Low Weighted – The visual presentation of the information objects that is used with the Search Tokens lets the users access detail information through semantic zooming. The bigger an information object gets, the more detail information is shown to the users. The user can zoom into an information object using pinching gestures or by taping on it. But also defining a filter criterion with a Search Token will enlarge matching information objects. Since the user generally will be interested in the detail information of the objects that match the defined filter (at least if it is defined with a weight bigger than 1) these objects should show as much information as possible.

Therefore the linear function of resizing matching information objects by multiplying their size with the weight of the filter defined with a Search Token is modified. The resize factor will be pushed for low weights by using a logarithmical adjustment (see Figure 35).

Damping the High Weighted – Information objects that have a very high resize factor, for example due to multiple matching filters with high weights, will on the other hand use much screen space and therefore possibly overlap other important information objects. Therefore the resize function is damped as soon as all detail information of an information object is visible to the user. From this point on, resizing the object will only make visible that a matching filter has been modified and not reveal more details to the users. Damping the resize function will therefore have no negative effects on the semantic zoom of an object, but it will help reduce overlapping and clutter in the information system (see Figure 35).

Combining the two Modifications – The figure below shows the resize function used with the Search Tokens. Both modifications described above can be handled with one logarithmic modification of the linear base function (blue line). The green graph shows how the linear function is modified to push the resize factor until the highest semantic zoom level of an information object is reached (last semantic zoom level). After that point the function is damped and soon will fall below the linear function.

For resize factors below 1, when an information object will get smaller than its default size, the linear function is used. There is a predefined minimal size for information objects (red graph).

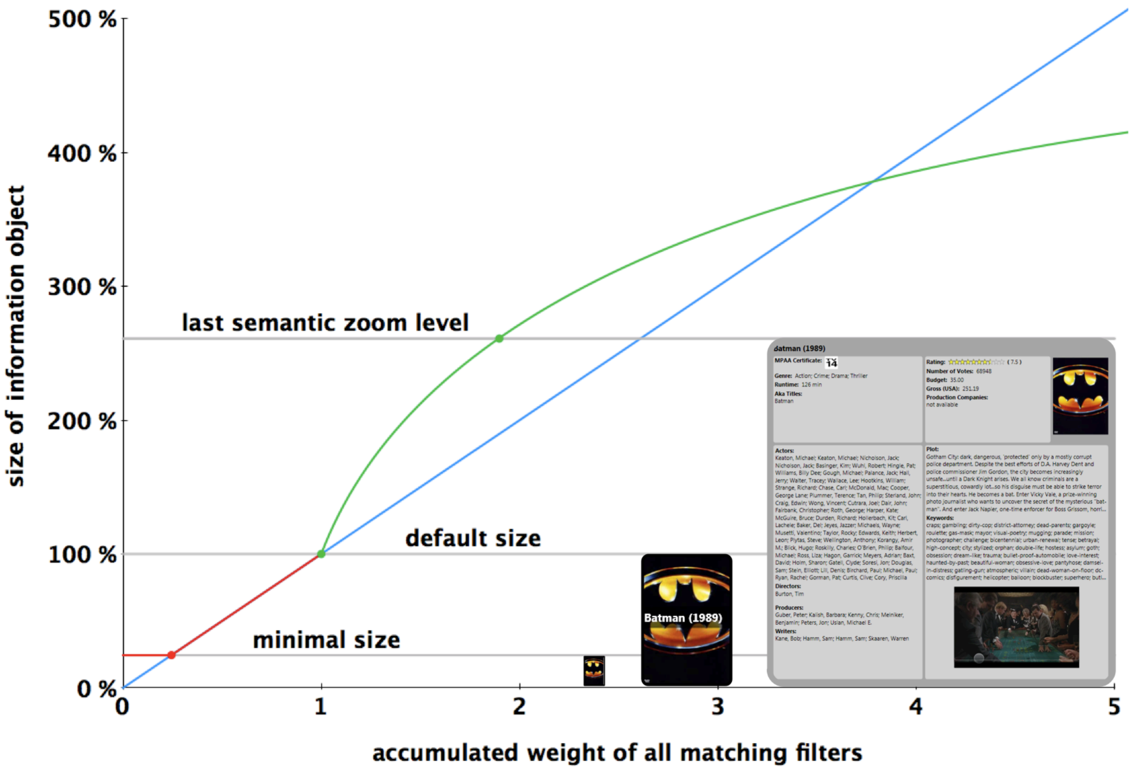

Figure 35: Graph of the resize algorithm.

Figure 36 shows a slightly simplified version of the resize algorithm described above. The method *filterNow* is called whenever a filter is modified. This happens when a user either alters the filter keyword of a Search Token or when the weight of a Search Tokens is changed.

```
public void filterNow(Filter focusedFilter){
   // resetting the size of all objects
   resetObjectsSize();
   // calculating the widths and heights
   // and saving them into the internal data structure Widths[] and Heights[]
   // this is done by every filter (Search Token) by itself one after another
   foreach (Filter f in Filters){
      f.filter();
   }
   // logarithmic modification of the linear default function
   // iterate over all information objects
   for (int i = 0; i < Movs.Count(); i++){
      // get the linear resize factor
      double mag = Widths[i] / MOVIE_DEFAULT_WIDTH;
      // for factors less than 1 use the linear factor
      if (mag <= 1)
         resizeObjectOnLandscape(VProps[i], Widths[i], Heights[i]);
      // for factors bigger than 1 calculate logarithmic modification
      else if (mag > 1)
         resizeObjectOnLandscape(VProps[i],
               MOVIE_DEFAULT_WIDTH * (Math.Log(mag, LOG_BASE) + 1),
               MOVIE_DEFAULT_HEIGHT * (Math.Log(mag, LOG_BASE) + 1));
   }
}
```

Figure 36: Code snippet – Resize algorithm.

First, all information objects will be reset to their default size with a call of *resetObjectsSize*. After that follows an iteration over all active filters. By calling the *filter* method of these filters, one filter after the other iterates through all information objects and multiplies its weight to the size of the matching objects. After that, the height and width of every information object is stored in the Heights and Widths data structure according to the linear base function.

Now the logarithmic modification is executed and the information objects are redrawn. Therefore again iteration over all information objects is necessary. First the linear resize factor is saved into the variable mag. If this factor is smaller than 1, the object is drawn with no modification by calling *resizeObjectOnLandscape*. If the factor is bigger than 1 the method is called with the logarithmically modified with and height. By calling the method *resizeObjectOnLandscape* the specific information object will be forced to draw itself instead of just saving the dimensions of the object in the internal data structure like before. This mechanism helps improve performance by reducing the CPU time of the graphic thread.

6 Evaluation

This chapter presents an evaluation that was carried out to examine the potential of the Search Tokens in comparison to other, less reality-based interaction techniques. The comparative evaluation makes an effort to answer the research question on how users can benefit of the tangible Search Tokens concept in co-located, collaborative information-seeking.

6.1 Goal of the Evaluation

As mentioned above, social collaboration in co-located environments play an important part in the users' process of information-seeking and knowledge work. To assess the impact of a reality-based user interface like the Search Tokens on the behavior of users in collaborative situations in comparison to other design approaches, a comparative evaluation study was accomplished. Two alternative designs besides the Search Tokens were developed that consciously follow different approaches: The virtual search tool and the classic search form (see Figure 39 and Figure 40). They all implement the basic concepts (sensitivity, highlighting and weighted Boolean) introduced with the concept of the Search Tokens, but differ in the degree of reality-based interaction. The goal of the three design alternatives was to compare the effect of the differences on the behavior of the users in a co-located, collaborative work setting.

6.2 Evaluation Setting

For the evaluation a dataset of approximately 200 movie objects was presented to the participants, visualizing them on a tabletop display (see Figure 37 a). The information objects had three different semantic zoom levels representing the different levels of detail. In the default representation only a poster of a movie was shown. The next level augmented the poster with the movie's title and the production year. In the last semantic zoom level the movie's genre, the IMDb[15]-rating, the gross and budget information, the directors' names and some of the actors' names where added as detail

[15] http://www.imdb.com – visited October 4, 2010

information. These were also the attributes that could be searched for by the participants using the different search tools.

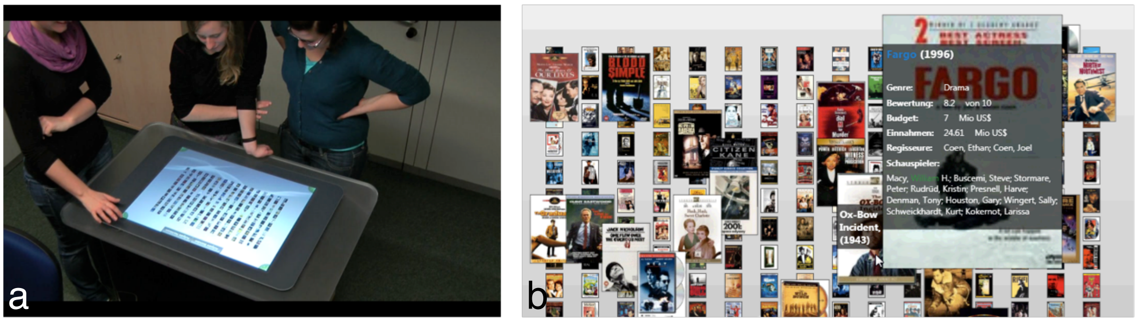

Figure 37: Evaluation setting – a) The multitouch tabletop display in the usability lab with three participants – b) The base visualization with the movie objects aligned in a regular grid.

The base visualization arranged all movie information objects in a grid (see Figure 37 b). Through the use of a multitouch display, several users were able to interact with the visualization simultaneously. The objects could freely be rearranged by the participants creating own collections (or clusters) of important movies for a specific assignment throughout the evaluation. Using the search tools triggered the semantic zoom of the information objects. In general, the more filter keywords a specific movie was matching the bigger it would get and the more detail information would become visible to the participants.

The tabletop display was placed in the middle of the usability lab and was lifted to a height so it could comfortably be operated standing around it (see Figure 37 a). This way the participants were able to freely and quickly move around the table to interact with the system and each other.

6.3 Alternative Design Approaches

To conduct the evaluation two additional designs to the Search Tokens, which will be introduced in the following section, were developed. Despite the fact of their different physical and graphical appearance, the three different designs share the same functionality and were used with the exact same base visualization during the experiment.

6.3.1 The Search Tokens

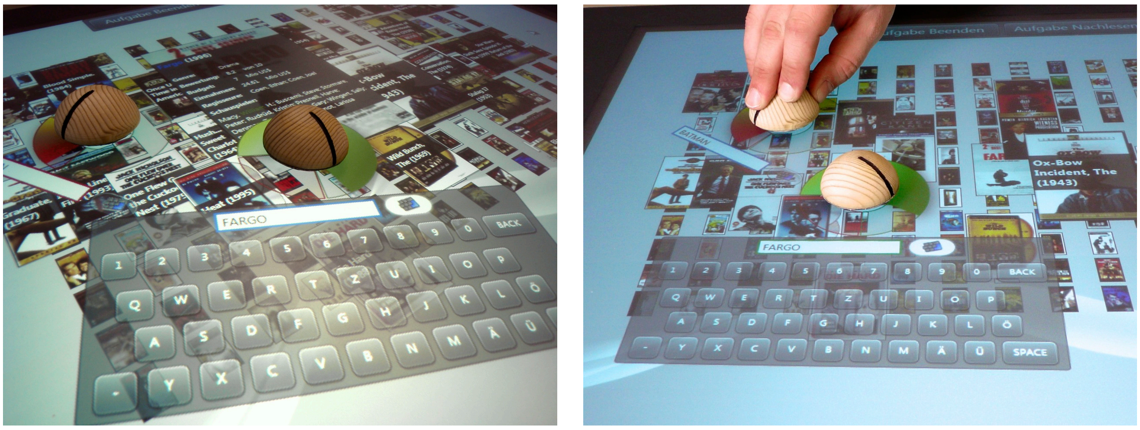

Figure 38: The Search Tokens as they were used in the evaluation.

To compare the three different designs, Figure 38 shows the version of the Search Tokens that was used in the evaluation. Before a new assignment had to be carried out by the participants, three Search Tokens were placed in different corners of the tabletop display. At the end of each assignment, this initial setting was restored. Along with the repositioning of the Search Tokens the grid with the movie objects was reset to its original state.

6.3.2 The Virtual Search Tool

The virtual search tool (see Figure 39) reproduces the functionality and the interaction concept of the physical Search Tokens on the multitouch display without the use of tangible user interface elements. It was designed to compare the influence of physical versus virtual appearance in the evaluation of the different tools. Taping on one of the tabletop's corners induces such a virtual search tool. The visualization is analog to the one of the physical Search Tokens.

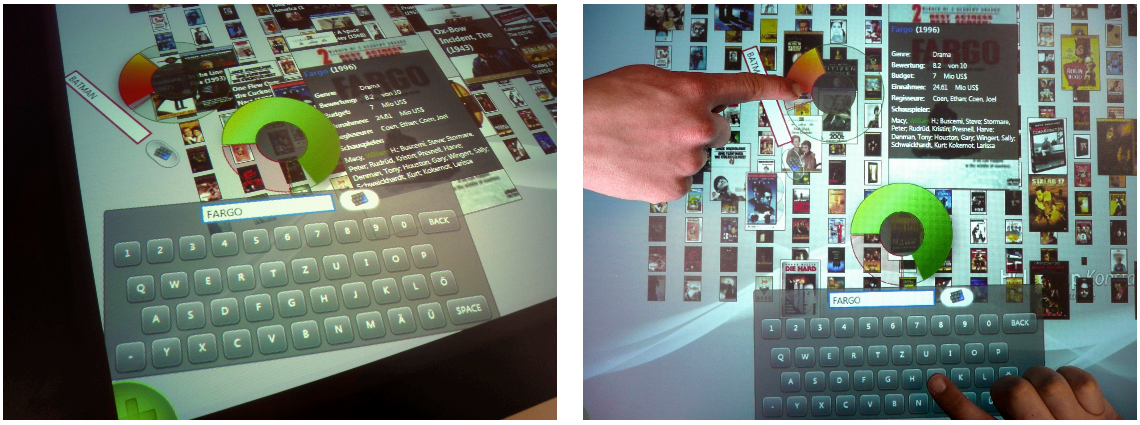

Figure 39: The virtual search tool as it was used in the evaluation.

The tool can be moved on the display using drag gestures and can be rotated using two-finger rotation gestures. By dragging the virtual search tool over the edge of the display, the visualization is removed and the filter will be reset, analog to lifting a Search Token of the tabletop. The alteration of the filter's weight is made by a finger gesture directly on the circular dial, analog to an "iPod Click Wheel" (see Figure 39).

6.3.3 The Classic Search Form

The classic search form (see Figure 40) was designed to contrast the evaluation with a conservative user interface that does not follow a very reality-based interaction concept. It consists of a single virtual keyboard, three text fields and three virtual sliders. Every text field can hold one filter criterion, which is entered using the stationary on-screen keyboard. The weight of a filter can be altered with the slider next to the corresponding text field. All three sliders can be handled simultaneously as in the other search tools described above. The whole search form is positioned on the lower edge of the tabletop display.

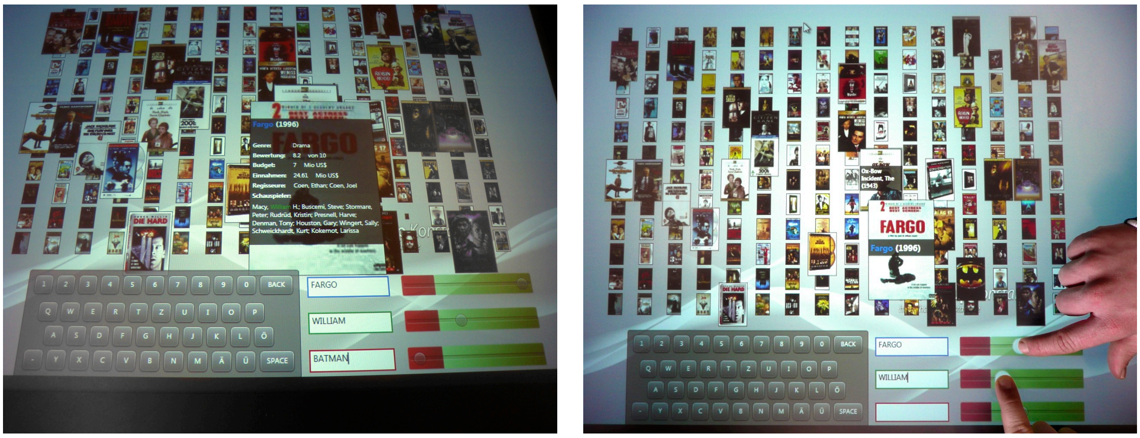

Figure 40: The classic search form as it was used in the evaluation.

6.4 Participants and Design

18 collegiate participants attended the evaluation study. Previous to the execution of the study, the subjects filled out a questionnaire to measure their general use of media technology and to collect the demographic data. The mean age was 23.5 years with a standard deviation of 3.9 years. 56 per cent of the participants were male. 89 per cent of the participants already collected experience with touch-sensitive displays.

The subjects were randomly divided into three-person-groups (triads). The resulting six triads passed all three terms of use – physical Search Token, virtual search tool and classic search form using a within subject design. Therefore, repeated measure analyses were used (Bortz & Döring, 2001). The sequence of the three tools was completely balanced over the six evaluation sessions.

6.5 Course of Action

After the questionnaire about media use, the triads explored the handling of the touch-sensitive tabletop display and the respective first tool independently. Thereafter, the triads got a systematic instruction through the investigator to ascertain a standardized knowledge base of the search tool between all triads and all participants. Thereafter followed a training stage to check whether all subjects understood the newly introduced search tool. This procedure was later repeated for all of the three different tools.

During the subsequent experiment, the participants completed four assignments for each tool. The level of difficulty increased for each assignment and started with rather simple search tasks (e. g. "How many 'Spielberg'-contributed movies are in the dataset?") and increased until more complex tasks (e.g. "Which is the highest rated drama movie, where one or more person/s with the name 'Coen' contributed?"). The last assignment for every search tool was formulated more open (e.g. "Find three DVDs for a movie night together."). The participants were encouraged to negotiate on three movies so that everyone would enjoy at least one of them. For every of the three search tools the assignments were just slightly modified using different names, genres, etc.

To solve the assignment consensus decisions had to be negotiated inside of the triad and the result had to be entered into a digital form. After the completion of the four assignments the participants individually filled out a questionnaire to rate the search tool they just used. This course of action was repeated for all three different interfaces (Search Tokens, virtual search tool and search form).

After the third tool was tested, the participants filled out a last questionnaire to compare all tools in consideration of different aspects (e.g. naturalness of interaction, personal preference, etc.). In a group interview at the end, open-ended questions were asked and the participants had the possibility to discuss the concepts with the investigator. The evaluation study took 1—1.5 hours for the participants. Everyone received 5 Euro as expenses.

6.6 Data Acquisition

The data of the evaluation was collected through the mentioned questionnaires and through observation of recorded video material. To analyze the video-recorded interactions the participants of the triads made, three observers simultaneously analyzed the material. Each observer exclusively concentrated on one participant. Concurrent to the video a metronome gave a signal every five seconds, splitting the assignments into intervals. Each observer used a table to mark whether the observed participant actively interacted with the system within an interval or not (as an example see Table 3).

Intervals (in seconds)	P 1	P 2	P 3	Simultaneous interaction
0—5		1		1
5—10	1			1
10—15	1			1
15—20	1	1	1	3
20—25		1	1	2
...				...

Table 3: Example for the video data acquisition.

This data was later used to measure the intensity of interaction with the different search tools. The degree of simultaneous interaction was used as a first, simple indicator for collaboration.

6.7 Results

The following section describes how intensive the participants interacted with the different tools and with the visualization. Then, the results from the questionnaires are discussed in consideration of the usage of the diverse tools.

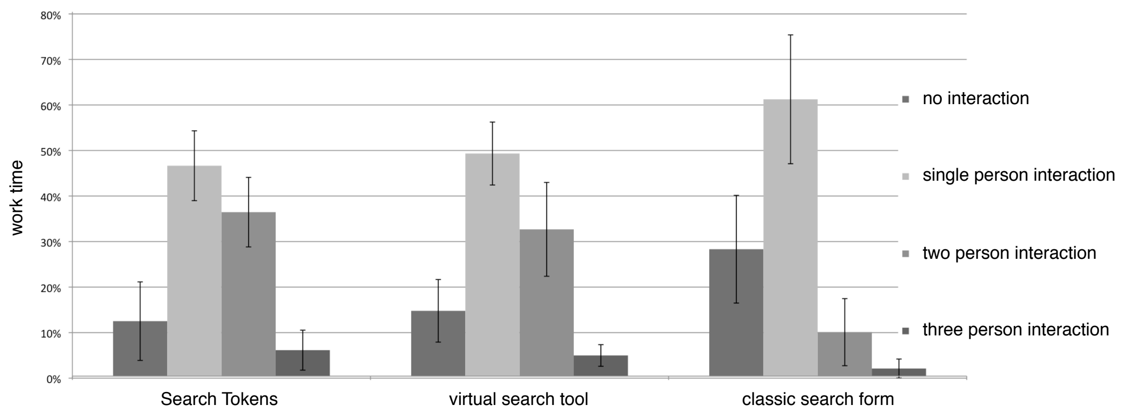

Figure 41: Evaluation – Simultaneous interaction with the three different interfaces: Search Tokens, virtual search tool and classic search form.

Figure 41 exposes that the participants avail themselves of the opportunity of parallel interaction with the user interface in the case of the virtual search-tool and the physical Search Tokens. The number of encountered interactions is divided by the number of 5-second intervals to receive evidence in per cent in consideration of the assignment's duration time (see Figure 41). During the use of the classic search form, a parallel usage of two persons could only be observed in 10 per cent of the time, whereas the virtual search-tool poses 32 per cent and the Search Tokens even 36 per cent of parallel interaction of two persons. Joint interactions of all three subjects of the triads could be observed only very rarely. In contrast, the solitaire interaction with a tool trough one person of the triad could be seen most frequently – in 61 per cent of the time – with the classic search form in comparison to the virtual search tool (49 per cent) and the Search Tokens (46 per cent). Also the time where no interaction at all was encountered was higher (at least double the time) with the classic search form (28 per cent) as with the two other interfaces, virtual search tool (14 per cent) and Search Tokens (12 per cent).

A similar picture was noticed through the subjective answers of the questionnaires, which were directly filled out by the participants after a particular term of use. On average the participants perceived the interaction with the classic search form fewest appropriate for collaborative information-seeking ($M = 3.06$, $SD = 1.55$; Scale from 1 "not appropriate" up to 7 "highly appropriate") in comparison to the Search Tokens ($M = 5.78$, $SD = 1.43$) and the virtual search tool ($M = 5.50$, $SD = 1.25$). The differences are statistically significant (classic search form versus virtual search tool: $t(17) = -6.27$, $p < 0.01$; classic search form versus Search Tokens: $t(17) = -6.50$, $p < 0.01$). The assessment of the Search Tokens and the virtual search tool did not differ significantly ($t(17) = -1.05$, $p > 0.1$).

Participants were asked whether the other two participants were rather active or passive during the assignments. The fewest activity of the others was assigned to the classic search form ($M = 5.39$, $SD = 0.98$; Scale from 1 "very passive" up to 7 "very active") in comparison to the Search Tokens ($M = 6.00$, $SD = 0.84$) and the virtual search tool ($M = 5.89$, $SD = 0.83$). The differences are partially significant (classic search form versus Search Tokens: $t(17) = -2.65$, $p < 0.05$) or rather not significant (classic search form versus virtual search tool: $t(17) = -2.03$, $p < 0.1$). In this case the difference between the Search Tokens and the virtual search tool is also not significant ($t(17) = -0.81$, $p > 0.1$).

	Question 1: Best suitable for collaborative information-seeking?[16]	Question 2: Personal preference?	Question 3: Most exhausting to use?
Search Token	59 %	47 %	22 %
virtual search tool	41 %	24 %	56 %
classic search form	0 %	29 %	22 %

Table 4: Summary of the comparative questionnaire.

The subjective appraisement of the tools, which was determined through the comparative questionnaire at the end of the experiment, exposes the differences between the Search Tokens and the virtual search tool. 59 per cent of the participants declared that the physical Search Tokens suit best for collaborative information-seeking, whereas the virtual search tool gets 41 per cent and the classic search form 0 per cent (see Table 4, question 1).

47 per cent of the participants also emphasized that the Search Token interface suits them best. On the second position was the classic search form (29 per cent) and on the third position was the virtual search tool (24 per cent)(see Table 4, question 2).

In addition the participants should specify how exhausting the interaction with the tools is (see Table 4, question 3). The answers showed a result pattern that argues for the two tools Search Tokens and classic search form, each with 22 per cent of the participants feeling most exhausted when using these tools. 56 per cent of the participants rated the virtual search tool as most exhausting tool concerning the interaction.

[16] One participant voted for two alternatives in question 1 and was therefore excluded from the analysis.

Key Aspects and Conclusion

- Goal of the evaluation was to find out whether a tangible user interface like the Search Tokens can have positive impact on the users' behavior in co-located, collaborative information-seeking tasks.
- The study compared three search tools that differ in the degree of reality-based interaction: the classic search form, the virtual search tool and the physical Search Tokens.
- The study showed that the users took advantage of the advanced possibilities of simultaneous interaction and collaboration with the Search Token interface and the virtual search tool compared to the classic search form.
- The users preferred the tangible user interface of the Search Tokens compared to the virtual search tool that shared the same visualization but was solely operated using multitouch gestures.

7 Conclusion, Discussion and Outlook

The design and development of the Search Token concept and the advancement of the Blended Library idea have strongly contributed to answering the research questions defined for this thesis. Throughout the work many insights into the topic of co-located, collaborative information-seeking have been gained that are not covered in the research literature so far. These findings have been made public through a number of publications[17].

Many of the new ideas presented in this thesis have evolved to a point were concrete design goals and practical interaction and visualization concepts can be suggested to use in future work. Some concepts may be the object of further enhancements. To conclude this thesis the four research questions again are critically discussed.

Design goals – The first research question is about finding the most crucial high-level design goals to support the development of collaborative information-seeking tools. The question is based on the insights of the theoretical models of information-seeking (Kuhlthau, 1993a)(Ellis, 1989) and reality-based interaction (Jacob et al., 2008) introduced in chapter 2 – Theoretical Foundations. Many of these models and concepts propose the importance of social interaction and collaboration during users' knowledge work process. Based on this theoretical work, design goals have been found that enhance the support of collaborative information-seeking.

One important design goal is to use natural and reality-based interaction techniques to help bring the users' natural skills from the real world into the virtual world of digital information systems. Another one proposes that tools to support individual information-seeking activities have to be built around a system that acknowledges the overall work processes involved. The idea of the

[17] Publications on the topic of the Search Tokens and the Blended Library:

(Demarmels, Huber, & Heilig, 2010)

(Heilig, Demarmels, Allmendinger, Gerken, & Reiterer, 2010)

(Heilig, Demarmels, Huber, & Reiterer, 2010)

(Reiterer, Heilig, Rexhausen, & Demarmels, 2010)

(Heilig, Demarmels, Rexhausen, Huber, & Runge, 2009)

Blended Library (see section 3.1 – The Blended Library) incorporates these concepts in a vision of the library of the future. Thereby the Blended Library draws upon other research contexts in the Human-Computer Interaction Group at the University of Konstanz. The term "blended interaction" summarizes the design goals behind these research projects (see section 2.4 – The Blended Interaction Paradigm).

Based on the definition of social search (Evans & Chi, 2008) (see section 4.1.1 – Social Search) different characteristics for collaborative information-seeking have been developed (co-located vs. remote, synchronous vs. asynchronous, explicit vs. implicit, shared interface vs. separate interfaces and shared strategy vs. separate strategies). These characteristics classify collaborative information-seeking tools and build additional design goals to choose from. Depending on the purpose of a specific tool a different set of characteristics has to be chosen.

As research in the field of natural interaction and information-seeking progresses the design goals that have been defined for this thesis will have to be adapted to the new insights. We are currently stepping towards a new age of human-computer interaction (Kaptelinin & Czerwinski, 2007). New interaction paradigms will certainly influence the design goals of future information systems.

Basic principles – This research question is about what basic interaction and visualization principles and techniques can be used to help translate the high-level design goals into a concrete implementation. Throughout the development process of the Search Token concept nine crucial principles emerged (see section 5.2 – Basic Principles of the Search Token Concept for detailed explanations):

- An elaborate **physical setting** helps integrate the information-seeking tool into the overall knowledge work process and combines advantages of the real-world library with the ones of digital information systems.
- **Multitouch** tabletop technology helps to democratize interaction with the digital world among the collaborators.
- **Tangible user interfaces** (Ishii & Ullmer, 1997) help making people aware of other collaborators' interaction by providing strong visual and physical affordance of the information-seeking tools and embodying digital functions through physical actions.

- Through the use of virtual **information landscapes** holding digital objects (Jetter, König, Gerken, & Reiterer, 2008), the data visualization takes advantage of the human abilities of visual-spatial orientation and remembering visual landmarks (Perlin & Fox, 1993).
- With **semantic zooming** a visualization principle is added that helps the information system to scale to different hardware platforms like mobile, PC and large, high-resolution displays. This helps supporting the users' in different contexts of the information-seeking process as it is showcased with the Blended Library.
- Using **dynamic queries** (Ahlberg, Williamson, & Shneiderman, 1992) as direct manipulative filter concept in information-seeking systems has already proven its success in earlier research projects (Gerken et al., 2009).
- **Sensitivity** (Tweedie, Spence, Williams, & Bhogal, 1994) is a concept that also contributes to the visual awareness of other collaborators' simultaneous interactions.
- The concept of weighting filter criterions based on **weighted Booleans** (Waller & Kraft, 1979) helps to provide users with an easy to understand filter mechanism that allows both browsing oriented access and complex Boolean analysis of datasets.
- By using **color highlighting** mechanisms to link filter criterions (Search Tokens) with the resulting information objects of an issued search, the concept introduced as collaborative brushing and linking (Isenberg & Fisher, 2009) is taken into account.

In the concept of the Search Tokens these principles have shown to suit many needs of co-located, collaborative information-seeking in the context of the Blended Library. Additionally other principles may further enhance the Search Token concept. One major flaw of the concept as it stands at the moment is that it only supports textual queries. Other sorts of filters (e.g. for numerical and temporal attributes) could certainly be implemented using similar tokens and visualizations and would greatly enhance the Search Token concept. Through the integration of automated information retrieval algorithms (see for example (Pickens, Golovchinsky, Shah, Qvarfordt, & Back, 2008)) the computers' abilities of fast data processing could further enhance the users' search activities.

Realization – With the realization of the Search Token prototype (as described in section 5.3 – Functional Description of the Search Token Concept) the high-level design goals are implemented into a working system by translating the basic principles into a concrete design. This prototype has been user tested and is iteratively enhanced both in the physical design of the tokens and the visualization of the Search Tokens.

Despite the positive findings of the evaluation and the encouraging user feedback, the practical implementation still may be object of future enhancement. Technical restrictions of the hardware and the software (small display resolution of the tabletop display and weak performance of the used software frameworks) are complicating the evaluation of the concepts.

Other improvements of the Search Token concept may lie in the implementation of additional features. One feature that for example should be enhanced in next iterations of the Search Tokens is the color highlighting, providing an even better link between the Search Tokens and their matching information objects in the result dataset.

Evaluation – The Evaluation that was described in chapter 6 – Evaluation has revealed the potential of the Search Tokens. The participants of the study liked the interaction techniques of the concept and found it a convincing way to enhance collaborative information-seeking in a co-located setting.

From a scientific standpoint however, the evaluation also left a lot of questions unanswered. One major point of critique was the method of how collaboration was measured. Simply looking for simultaneous interaction of multiple users is certainly not the best indicator for collaboration. In a subsequent user study additional channels of collaboration (verbal and non verbal communication, body gestures, etc.) as well as different collaboration patterns the users carried out were recorded. At the time of this thesis however the interpretation of the measured evaluation data has just begun and could therefore not be included.

The concept of the Search Tokens is a very promising idea in the context of co-located, collaborative information-seeking. Many insights in the scientific field could already be gained. These insights will become even more relevant by further evolving the concept of the Search Tokens and the Blended Library as a vision of information-seeking in the library of the future.

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Appendix A: Evaluation Documents

Appendix A includes the documents that were handed to the participants during the evaluation described in chapter 6 – Evaluation. The documents are all written in German.

- **Welcome text** that was handed out before the evaluation session started.
- **Consent form** that had to be signed before the evaluation.
- **Questionnaire** about the **usage** of computers, tangible user interfaces and multitouch interfaces.
- **Questionnaire** about the **search tool** that was just tested by the participant.
- **Questionnaire** to **compare** the three different search tools at the end of the evaluation session.

Begrüßung

Zunächst möchten wir uns bei Ihnen bedanken, dass Sie sich bereit erklärt haben, an unserer Untersuchung teilzunehmen. Bevor es nun gleich losgeht, wollen wir Ihnen mit Hilfe dieser kurzen Einführung vermitteln, um was es uns bei dieser Untersuchung überhaupt geht und welche Rolle Sie dabei spielen.

In der Bibliothek gibt es einen abgegrenzten Bereich, in welchem der Benutzer unter anderem Videomitschnitte, Tonträger, CD's zu Büchern und mittlerweile auch DVDs aktueller Filme vorfindet – die **Mediothek.**

Um die Vielzahl an Medien überschaubarer zu machen und einen guten Einstieg in den Datenraum zu ermöglichen, entwickeln wir zur Zeit eine neue Version von MedioVis, genannt **MedioVis 2.0**. Dieses Produkt befindet sich noch in der **Entwicklungsphase** wobei Sie ins Spiel kommen, denn der beste Weg für uns, ein benutzerfreundliches Produkt zu erhalten, ist dem Benutzer direkt bei der Arbeit mit den Systemen zuzuschauen und Ergebnisse zu analysieren.

Wir werden Sie zunächst bitten bestimmte Aufgaben zu bearbeiten. Sobald Sie den Aufgabenteil abgeschlossen haben, werden wir abschließend ein kleines Interview mit Ihnen führen, in welchem Sie die Möglichkeit haben Ihre **eigene Meinung** bezüglich **MedioVis 2.0** verstärkt vorzubringen.

MedioVis 2.0 steht also bei dieser Untersuchung auf dem Prüfstand und nicht Sie als Benutzer. Sie sind vielmehr in der Rolle des Prüfers, welcher uns die Möglichkeit gibt, Benutzungsprobleme mit den Systemen zu erkennen und letztendlich zu beseitigen.

Für die Auswertung der gewonnenen Daten wäre es allerdings sehr hilfreich, wenn wir den Test auf Video aufzeichnen könnten. Hierfür benötigen wir allerdings ihr Einverständnis, wobei wir uns im Gegenzug verpflichten, das Videomaterial anonymisiert und lediglich zu Auswertungszwecken zu verwenden. In diesem Zusammenhang haben wir ein separates Dokument vorbereitet, welches Ihnen von unserem Prüfer vorgelegt wird.

Abschließend wünschen wir Ihnen viel Spaß und möchten uns noch einmal für Ihre Teilnahme bedanken!

Einverständniserklärung

Bitte lesen Sie die folgenden Zeilen aufmerksam durch.

Um eine bessere Auswertung der gewonnenen Daten zu erreichen, werden wir eine Videoaufzeichnung des Tests vornehmen. Durch die Unterzeichnung dieses Formulars erklären Sie sich damit einverstanden. Im Gegenzug garantieren wir Ihnen die Aufzeichnung anonymisiert und lediglich zu Auswertungszwecken zu verwenden.

Sie haben jederzeit die Möglichkeit, die Untersuchung abzubrechen!

Hiermit erkläre ich mich mit den oben genannten Punkten einverstanden:

Name, Vorname ____

Unterschrift ____

Datum ____

Hiermit verpflichtet sich die Untersuchungsleitung, die Videoaufzeichnung sowie sämtliche sonstigen gewonnenen Daten lediglich zu Auswertungszwecken im Rahmen dieser Untersuchung zu verwenden:

Name, Vorname ____

Unterschrift ____

Datum ____

Fragebogen zum Nutzungsverhalten

1. Code-Nr: ____
Bitte kreuzen Sie auf den Antwortskalen der jeweiligen Fragen die Ihnen spontan richtig erscheinende Antwort an. Die Daten werden anonymisiert ausgewertet.

2. Geschlecht: ______
3. Alter: ______

	jeden Tag	mehr-mals pro Woche	einmal pro Woche	einmal im Monat	wenige r	Nie / habe keinen
4. Wie häufig arbeiten Sie am Computer?	❑	❑	❑	❑	❑	❑
5. Wie häufig schauen Sie Spielfilme?	❑	❑	❑	❑	❑	❑
6. Wie häufig nutzen Sie die Mediothek der Universität Konstanz?	❑	❑	❑	❑	❑	❑
7. Wie häufig arbeiten Sie in Ihrem Studium/Beruf im Team?	❑	❑	❑	❑	❑	❑
8. Wie häufig nutzen Sie ein Touchdisplay, also einen berührungssensitiven Bildschirm (z.B. beim Bahn- oder Bankautomaten)?	❑	❑	❑	❑	❑	❑
9. Wie oft haben Sie bereits einen Multitouch-Tisch benutzt?	❑	❑	❑	❑	❑	❑
10. Wie oft haben Sie bereits Computer über greifbare Gegenstände gesteuert (z.B. Bauklötze, Museumsobjekte etc.)?	❑	❑	❑	❑	❑	❑

11. Wie motiviert sind Sie, an dieser Studie teilzunehmen?
❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
sehr unmotiviert teils/teils sehr motiviert

12. Wie skeptisch sind Sie im Allgemeinen gegenüber „Neuen Technologien“ eingestellt?
❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
sehr unskeptisch teils/teils sehr skeptisch

13. Wie oft arbeiten Sie mit anderen Menschen in Ihrem Studium/Beruf zusammen?

❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
nie gelegentlich oft

14. Wie oft Arbeiten Sie mit anderen Menschen an einem Computer zusammen?

❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
nie gelegentlich oft

15. Für wie sinnvoll halten Sie computerunterstützte Teamarbeit für ihr/en Studium/Beruf?

❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
sinnvoll neutral weniger sinnvoll

16. Wie angenehm finden Sie Teamarbeit an einem Computer?

❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
angenehm neutral weniger angenehm

17. Wie oft arbeiten Sie mit unbekannten Menschen zusammen?

❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
nie gelegentlich oft

18. Wenn Sie mit anderen Menschen zusammenarbeiten, würden Sie sich eher als aktiv oder passiv bezeichnen?

❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
sehr aktiv mäßig aktiv sehr passiv

19. Wie oft recherchieren Sie für Ihre/n Studium/Beruf?

❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
nie gelegentlich oft

20. Wie oft recherchieren Sie in Ihrem Studium/Beruf zusammen mit anderen Menschen?

❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
nie gelegentlich oft

21. Wie oft recherchieren Sie in Ihrem Studium/Beruf zusammen mit anderen Menschen an einem Computer?

❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
nie gelegentlich oft

Vielen Dank für das Ausfüllen des Fragebogens!

Fragebogen zu den Werkzeugen

Code-Nr.:______________________ Werkzeug:______________________

Bitte kreuzen Sie auf den Antwortskalen der jeweiligen Fragen die Ihnen spontan richtig erscheinende Antwort an.

1. In welchem Ausmaß waren Sie in der Lage die Aufgaben mit dem angebotenen Werkzeug zu beantworten?

   ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
   überhaupt nicht etwas vollständig

2. Wie natürlich kamen Ihnen Ihre Interaktionen mit dem Werkzeug vor?

   ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
   extrem unnatürlich teils/teils völlig natürlich

3. Wie vollständig wurden all Ihre Sinneskanäle angesprochen?

   ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
   unvollständig mäßig vollständig

4. Wie bewusst haben Sie die reale Umgebung während den Aufgaben wahrgenommen?

   ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
   überhaupt nicht teils/teils sehr bewusst

5. Waren Sie in der Lage vorauszusehen, was als Auswirkung Ihrer Handlungen passiert?

   ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
   überhaupt nicht etwas vollständig

6. In welchem Ausmaß fühlten Sie sich im Anschluss an die Bedienung verwirrt?

   ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
   überhaupt nicht etwas sehr desorientiert/verwirrt

7. Wie vertieft waren Sie in die Bearbeitung der Aufgaben in der virtuellen Darstellung?

   ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
   nicht etwas völlig

8. Wie ablenkend empfanden Sie die Bedienung des Werkzeugs?

   ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
   überhaupt nicht etwas sehr ablenkend

9. Wie schnell konnten Sie sich an das Werkzeug gewöhnen?

   ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
   überhaupt nicht langsam in weniger als einer Minute

10. Wie gut beherrschten Sie am Ende der Sitzung Ihrer Meinung nach die Interaktion mit dem Werkzeug?

    ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
    nicht gut ziemlich gut sehr gut

15. Für wie sinnvoll halten Sie computerunterstützte Teamarbeit für ihr/en Studium/Beruf?

❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
sinnvoll neutral weniger sinnvoll

16. Wie angenehm finden Sie Teamarbeit an einem Computer?

❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
angenehm neutral weniger angenehm

17. Wie oft arbeiten Sie mit unbekannten Menschen zusammen?

❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
nie gelegentlich oft

18. Wenn Sie mit anderen Menschen zusammenarbeiten, würden Sie sich eher als aktiv oder passiv bezeichnen?

❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
sehr aktiv mäßig aktiv sehr passiv

19. Wie oft recherchieren Sie für Ihre/n Studium/Beruf?

❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
nie gelegentlich oft

20. Wie oft recherchieren Sie in Ihrem Studium/Beruf zusammen mit anderen Menschen?

❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
nie gelegentlich oft

21. Wie oft recherchieren Sie in Ihrem Studium/Beruf zusammen mit anderen Menschen an einem Computer?

❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑ ---- ❑
nie gelegentlich oft

Vielen Dank für das Ausfüllen des Fragebogens!

Fragebogen zu allen Werkzeugen

Code-Nr.:______________________

1. Welches Werkzeug hat Ihnen persönlich am meisten zugesagt?

   ❑ Sucheingabemaske
   ❑ digitales Suchwerkzeug
   ❑ physisches Suchwerkzeug

2. Mit welchem Werkzeug haben Sie die Aufgaben Ihrer Meinung nach am besten lösen können?

   ❑ Sucheingabemaske
   ❑ digitales Suchwerkzeug
   ❑ physisches Suchwerkzeug

3. Welches Werkzeug ist Ihrer Meinung nach am natürlichsten zu Bedienen?

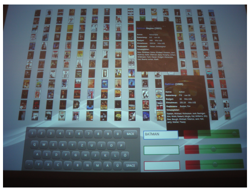
   ❑ Sucheingabemaske
   ❑ digitales Suchwerkzeug
   ❑ physisches Suchwerkzeug

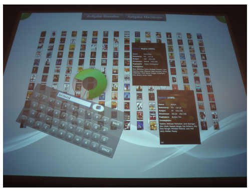
4. Welches Werkzeug ist Ihrer Meinung nach am anstrengendsten zu Bedienen?

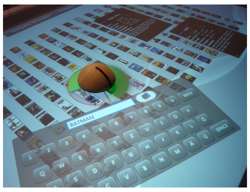
   ❑ Sucheingabemaske
   ❑ digitales Suchwerkzeug
   ❑ physisches Suchwerkzeug

5. Welches Werkzeug eignet sich Ihrer Meinung nach am besten für gemeinsames Recherchieren?

   ❑ Sucheingabemaske
   ❑ digitales Suchwerkzeug
   ❑ physisches Suchwerkzeug


Sucheingabemaske


digitales Suchwerkzeug


physisches Suchwerkzeug

6. Hatten Sie bestimmte Probleme bei der Bedienung eines Werkzeuges? Wenn ja, bitte notieren Sie welche es waren:

____

____

____

____

____

____

____

____

____

____

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Vielen Dank für das Ausfüllen des Fragebogens!

Appendix B: Video Material

The different videos that showcase the concepts of the Search Tokens and the Blended Library can be found on the attached DVD.

- Meet Me in the Library! – *A video demonstration of the Search Token concept as a co-located, collaborative information-seeking tool in the Blended Library.*

- Weighted Boolean Filter Queries – *A video demonstration of the Search Token interaction concept.*

- Query by Example – *A video demonstration of a concept where real-world information objects (DVDs) are used to search for related information in the Blended Library information system.*

- Search, Explore and Navigate – *A video demonstration of the fundamental visualization and interaction techniques used in the Blended Library information system.*