Requirements to a Search Engine for Semantic Multimedia Content

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ABSTRACT

The authors investigate user requirements regarding the interface design for semantic multimedia search and retrieval based on a prototypical implementation of a search engine for multimedia content on the web. Thus, unlike existing image or video search engines, they are interested in true multimedia content combining different media assets into multimedia documents like PowerPoint presentations and Flash files. In a user study with 20 participants, the authors conducted a formative evaluation based on the think-aloud method and semi-structured interviews in order to obtain requirements to a future web search engine for multimedia content. The interviews are complemented by a paper-and-pencil questionnaire to obtain quantitative information. As a result, the authors elicit requirements to a web search engine for multimedia content. Among them, scalability and personalization of the presented information are identified as the main goals. Based on the requirements, they present mockups demonstrating the user interface of a future multimedia search and retrieval engine.

Keywords: *Evaluation, Human Factors, Measurement, Multimedia Search, Semantic Integration, User Interface Design*

1. INTRODUCTION

Multimedia content, which is provided by PowerPoint presentations or Flash documents, is widely adopted and can be found in any domain. Despite the growing interest in multimedia web search, most major web search engines currently offer only limited multimedia search functionality. Unlike existing image or video search engines, the content a multimedia search engine has to deal with is the coherent combination of different types of media assets such as images, videos, audios, and text. Those media assets can be animated or rearranged by interactions (Candan & Sapino, 2010). The semantic within multimedia documents is given through relations dealing with time and space of media assets (Boll, Sandhaus, Scherp, & Westermann, 2007), e.g., duration of a video, width, height, and position of an image, but

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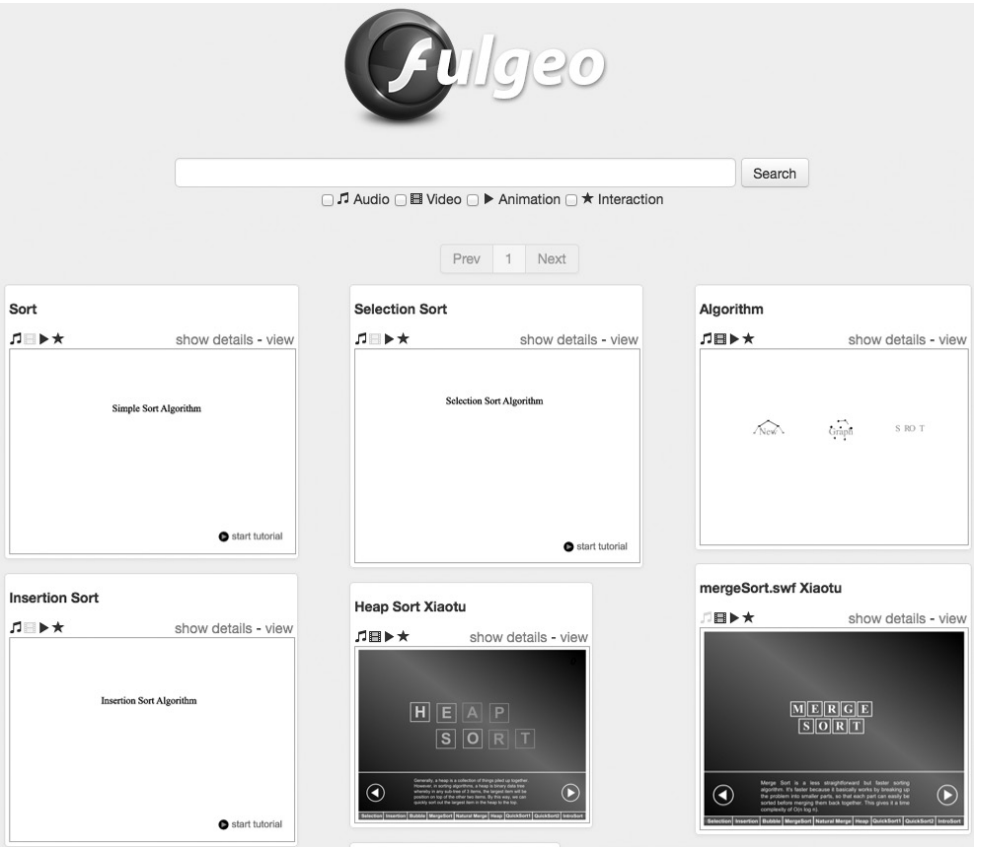
these are just partially taken into account by previous systems. Research on search engines dealing with a single media type like images and videos is well established and there exist studies that investigate how users apply media search engines (Maniu, O'Hare, Aiello, Chiarandini, & Jaimes, 2013; Kofler & Lux, 2009). However, regarding search and retrieval of *true* multimedia there is a gap in the research. Thus, we have developed an early prototype of a search engine for multimedia content on the web (Tingvold, Stohr, Schneider, & Amundsen, 2013)[1] (cf. Figure 1). The prototype offers users to search and explore for multimedia content. The goal of this early search engine was to provide users an initial idea of what a retrieval system for true multimedia could look like and to use this system to bootstrap requirement elicitation and detailed understanding of users' needs for semantic multimedia search. On the basis of this prototype, we conducted a user study evaluating the features for a future multimedia search engine. The current prototype is developed for keyword-based queries only. There are filters for audio, video, animation and interaction. These filters are applied by logical OR operators. The preview of the multimedia documents in the result list indicates if the document contains media assets fulfilling the filter. The thumbnails, which show the first frame or the first slide of the multimedia document, are of different sizes, starting with larger ones in the upper

Figure 1. Fulgeo search interface and result view pagination is used and limits the result list to 20 documents per page. Overall, the prototype has about 4000 multimedia documents in the database.



position to smaller ones in the lower position of the results page. Hovering over a thumbnail shows an animated preview of the document. Clicking on a document opens a detail view in the lower part of the search engine's window.

In the subsequent sections, we present the related work in multimedia search and studies on media search engines. In Sections 3 and 4, we describe the conducted user study and its results. Based on these results, we derive requirements to a future multimedia search engine in Section 5. We designed mockups combining good features of the existing prototype, with new requirements collected from the survey, and further ideas derived by the interview section (Section 6). Finally, we discuss the overall results and the limitations of our study (Sections 7 and 8).

2. RELATED WORK

Various media retrieval systems have been developed in the past like the MEMORAe project (Merzougui, Djoudi, & Behaz, 2012), where ontological knowledge is used for indexing and searching educational videos. Breaking the barrier of a single media modality, there are approaches for semantic cross-media search and retrieval like the semantic search engine Squiggle (Celino, Valle, Cerizza, & Turati, 2006) for images and audio. The FLAME framework (Flash Access and Management Environment) (Yang, Li, Wenyin, & Zhuang, 2007) is considered to be the so-far most comprehensive work on multimedia search. It supports retrieval based on some spatial and simple interaction constraints. Regarding the use of media retrieval systems, there have been some empirical investigations conducted in the past. Hearst (Hearst, 2009) states that there are three main search behaviors in web search: fact finding (looking for specific facts or pieces of information), information gathering (the collection of information from multiple sources), and browsing (visiting web pages without particular goal). Kofler and Lux (Kofler & Lux, 2009) conducted an evaluation of user intentions within image search. They conclude that existing taxonomies and models do not represent the users' intent while searching for multimedia content sufficiently. Maniu et al. (Maniu, O'Hare, Aiello, Chiarandini, & Jaimes, 2013) analyzed web server logs and all user actions during search sessions. They identified differences in search behavior caused by the different categories of search. Those categories are derived from the analysis of the server logs. They also conclude that current models and thus, interfaces, do not exactly represent the user's intent while searching for multimedia content.

3. USER STUDY

In July and August 2013 we conducted a user study with 20 subjects (eight female). The average age was 26-year-old (standard deviation (SD) = 2.87), ranging from 22- and 34-year-old. A pretest checked minimum command of English (required to use the prototype) and computer skills. This is important to obtain feedback from users which are familiar with existing search engines. The majority (16 subjects) said to have "worked a lot with search engines" (rating 6 and 7 on a 7-point Likert-scale), while the others rated themselves as intermediate users (rating 3 to 5). The experience distribution about multimedia search was nearly similar (13 experienced users and one novice user). Special consideration was given to the subjects' diversity regarding educational background and profession in order to avoid bias by a specific population group (Miles & Huberman, 1994). The sample consisted of bankers, cooks, doctors, machinists, computer science students, media and communication science students, and students of teaching.

3.1. Apparatus and Data Set

At the time of the user study, the prototypical multimedia search engine was filled with about 4000 multimedia documents crawled from the web. These multimedia documents cover terms related to the topic climate change and global

warming. The experiment was conducted at a normal workplace using the same laptop with a 19-inch screen.

3.2. Tasks

Every subject had to solve four tasks. The main aim was to find specific multimedia documents. For solving the tasks, the subjects had to use the different features offered by the engine. The tasks were of different levels of complexity. The first task was to find a document and to open it in a new window or tab. This document had to fit to the query "Climate conference in Kyoto".

In the second task, the subjects had to apply the filter for animations to find a multimedia document in the context of the "Greenhouse effect".

In the third task, they had to use the detail view and the highlighted keywords to find a document, which contains most occurrences of the keywords "Climate change, sea level, glacier, Kyoto, and climate protection".

In the last task, a subject had to start an animation or activate an interaction within the context of "Climate change and glacier". The tasks were motivated by a task scenario, wherein the subject is supposed to explain climate change to pupils using multimedia. No specific introduction was given to the subjects on how to use the search engine. Thus, the subjects had to solve the tasks based on their prior knowledge from existing search engines.

3.3. Procedure

At the beginning, we informed the subjects about the goals of the study and asked them to sign an informed consent form. We asked the subjects to write down their first impressions of the prototypical multimedia search engine. Then we asked the subjects to conduct the different search tasks. While conducting the tasks, the subjects were encouraged to think aloud. Subsequently, the subjects were asked to fill in a paper-and-pencil questionnaire. Here, a set of 19 closed-questions taken from the IsoMetrics (Gediga & Hamborg, 1999) questionnaire (version 2.01) were chosen and adapted to assess the prototype. The IsoMetrics questionnaire is a catalogue of questions aiming at summative and formative evaluations of software. Questions in IsoMetrics address part 10 of the DIN EN ISO 9241, which defines principles of ergonomic user interfaces. Thus, IsoMetrics focuses at an evaluation of usability and user-centered design.

We focused on questions about the suitability for executing the task, for learning the application and individualization of the application, the conformity with user expectations, self-descriptiveness, controllability, and error tolerance. In addition, we asked specific questions regarding search and exploration of multimedia content: The features of the current prototype are about filtering by medium type, thumbnail preview of multimedia documents, the detailed view of a selected document, and the ranking by size to support the prediction of relevance. The subjects answered the questions on a 7-point Likert scale.

In addition, open-questions were asked to the subjects, e.g., "what do you like about the search engine", "what do you not like about the search engine", "what do you think is missing (any kind of design or functionality)?", and "what do you believe might improve the usability of the search engine?". These open questions were investigated in a semi-structured interview in order to explore emergent meanings and intentions of the subjects in context (Myers, 2009).

4. RESULTS

4.1. Task Execution

The mean duration for all sessions was 39 minutes (SD = 9min.), mean processing time for task 1 is three minutes (SD = 1 min.), task 2 also three minutes (SD = 2 min.), task 3 four minutes (SD = 2 min.), and task 4 three minutes (SD = 1 min.). All subjects were able to successfully accomplish their tasks. Considering the feedback from the subjects that they assess the tasks to be gradually more challenging but never unsolvable and considering the measured execution times, suggests that task demand was

adequate. This fits the intention of an accessible test design.

4.2. User Satisfaction

In detail we asked the following amount of questions from the categories. Abbreviations in brackets will be used in the latter and on the visualizations for the evaluations: S*uitability for learning the application* (4 items, L.1-L.4), c*ontrollability* (2 items, C.1-C.2), *suitability for executing the tasks* (2 items, T.1-T.2), and questions about the specific *features for multimedia search* (4 items, F.1-F.4).

4.2.1. Suitability for Learning the Application

Most subjects predominantly agreed to the statement L.1: "The interface of the search engine is understandable at first glance." (mean (M) = 6.2; SD = 1.12)(cf. Figure 3). Also most of the subjects predominantly agreed to L.2: "The search engine is designed in such a way, that functionality not yet known could be learned by trying out." (M = 6.15), with lower SD = 0.91. A higher deviation and lower agreement was received for L.3: "It did not take long time before I learned to operate the search engine." (M = 5.75; SD = 1.68). L.4: "I don't have to remember a lot of details to operate the search engine", reached a higher agreement and a lower deviation again (M = 6.35; SD = 0.96). Overall, the interface was easy to understand, but there were some features which require learning or explanation (See Figure 2).

4.2.2. Controllability

The results for the L-items were supported by C.1: "Handling the multimedia search engine is easy." (M = 5.8; SD = 0.98) and C.2: "The engine can only be used in a rigid way." (M = 4.05; SD = 1.66).

4.2.3. Suitability for Executing the Task

Suitability for task was represented by the following questions T.1: "The search engine permits to enter queries just the way it is necessary for searching multimedia content." (M = 5.7; SD = 1.35) confirmed the initial keyword as approach for searching multimedia content. Nevertheless, generating and representing results need some rework, as T.2: "The results found by the search engine match my queries.", only got an "agree" (M = 4.85; SD = 1.46).

4.2.4. Features for Multimedia Search

The questions which were used to evaluate the specific features of multimedia search are about filtering by medium type (F.1), thumbnail preview of multimedia documents (F.2), the detailed view of a selected document (F.3), and

Figure 2. User ratings about learnability shown as box plots

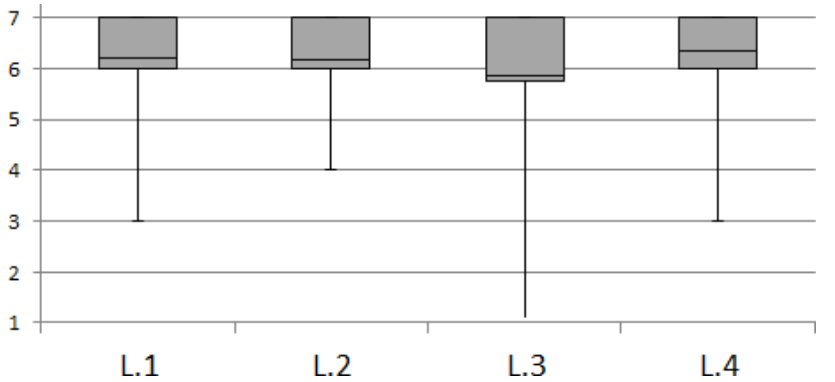
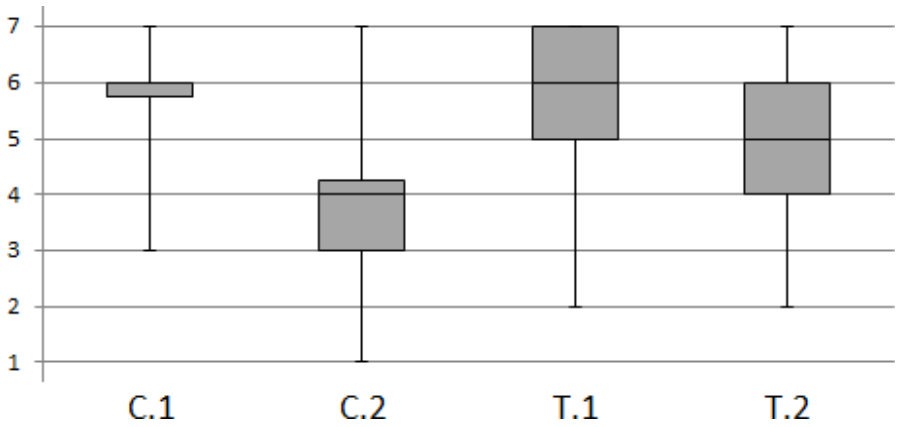


Figure 3. Ratings of controllability and suitability for executing the task shown as box plots

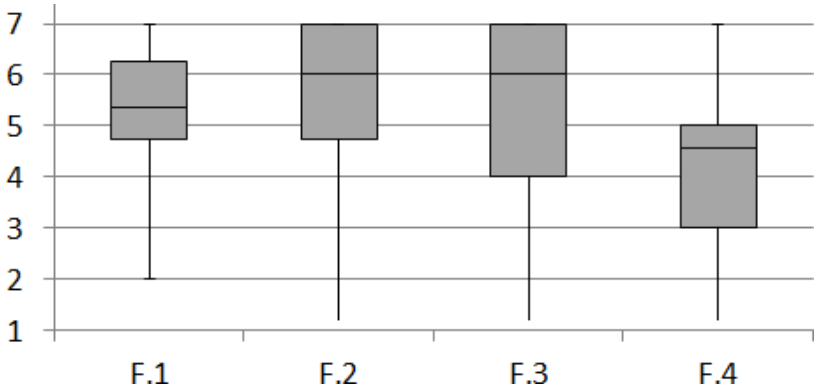


the ranking by size to support the prediction of relevance (F.4). The median values of the ratings regarding the specific features of our prototype range between 4 and 6 (cf. Figure 4). As can be seen from Figure 4, all results were in median higher than 5.5. But the detail view needs improvement.

4.3. Semi-Structured Interviews

We conducted semi-structured interviews and applied a bottom-up process to analyze the results and obtain concepts from the detailed analysis of the collected data (codification) (Young, Kuo, & Myers, 2012). Overall, we can state that the subjects enjoyed using the multimedia search engine. Eleven subjects enjoyed the detail-view of the multimedia documents and found it, e.g., "very helpful" and "good for a preview so you do not have to open several pages". Eight subjects mentioned the four filter categories (audio, video, animation, interaction) positively, assuming these filters facilitate their research, especially because they can use multiple filters simultaneously. Six subjects liked the preview-animation as a concept, despite some technical issues (which were due to encoding problems). Other positively attributed comments by at least three subjects are: pleasant look, clarity, simple to use, simple to understand or conformity with user habits

Figure 4. Box plots showing the ratings of multimedia search features



(see Google). Also, positively mentioned were automatic opening of the documents in a new tab, a good overall impression, automatic text highlighting of the query in the detailed view, a logo to restart a search, and the simultaneous presentation of the result page and the document details. Regarding aspects that could be improved, seven subjects mentioned that they found the results page unstructured, irritating, or chaotic, as they rather prefer representation of relevance by either size of thumbnails or a grid layout with descending order, but not both combined in one layout. Six subjects mentioned missing meta-data such as the authors, date, and URL. Four subjects mentioned to be confused by the imprecise use of filters. Three subjects did not understand the meaning or concept of the animation, which starts playing when the user hovers over a thumbnail of a document shown in the result list. These three also mentioned that the icons and names for the filters are not self-explanatory enough. They proposed to add tool tips, which are shown when hovering over the icons.

5. REQUIREMENTS ELICITATION

Based on the results of the questionnaire, the user feedback in the semi-structured interviews, and existing literature we derive requirements for a future multimedia search engine. We organize the requirement along the different existing as well as new functional aspects of the prototype. For all requirements, we also provide further details on the user feedback.

5.1. Search Bar

The search interface of a multimedia search engine should offer an error tolerant autocompletion. According to Morville (Morville & Callender, 2010) queries should be easy to formulate, adapt and change according to the user's needs and preferences and direct the user to results, even if the user does not know exactly what he or she is looking for. More filters, which cover metadata, like author or date of creation, should be offered. To avoid an overload of the interface these additional filters can be hidden in an advanced search interface. These requirements to the search bar are suggested by analyzing the user comments, where eleven users stated that they would feel more supported by an autocompletion feature and less restricted by the implementation of further filter options. Six users suggested outsourcing more options, like further filters, into an advanced search interface.

5.2. Result Page

A multimedia search engine should offer several options or styles to view the result page. Two possibilities were suggested:

1. Arrange results strict from top to bottom. Representation of relevance is given from top to bottom in ascending order, without the representation of relevance by thumbnail size;
2. Results are presented in a grid layout with the same thumbnail sizes, but users can arrange their appearance on basis of adjustable relevance options or rearrange via drag-and-drop. The users are allowed to choose the appearance of relevance manually, so that a user can choose the relevance by size within the grid layout, like it is provided by the current prototype. This manually chosen relevance appearance prevents the user from being confused by a chaotic layout.

Overall, the subjects prefer consistency and clarity over style. As rationale for this requirement, we consider that some subjects rather want a simple list or at least the option to show the results as a list of names or headlines.

5.3. Thumbnail View

The aim of snippets is to support the user in predicting the relevance of result items. Therefore, the representation should be clear, self-explanatory, and provide enough informa-

tion. The thumbnail view should provide icons for filters, which are more visible and, where the function, if a certain media type is included or not, is clear. As known from other search engines, the headlines should provide a link to the URL of the original document. Besides providing a link, a download button might also be useful. These requirements are supported by half of the subjects: they nearly ignored the icons for the different filters. Furthermore, four users thought that these icons are for interaction. They tried to click on the headers of the thumbnail in order to obtain the entire multimedia document. As there is a difference in "show-details" and "view", five users suggested to state the difference between those more apparently. Nevertheless, five users did not want or do not need snippets in the "detail view".

5.4. Detail View

The suggestion for the detail view is to enable the user to scroll through the whole text, search for further keywords within that document and to use the highlighted keywords as markers for navigating between them. When a user clicks on the highlighted keyword and then jumps to the next highlighted keyword, the preview image of the document will also change according to the text. Customization by resizing or moving the detail view window should be supported. Also adding buttons for navigating between detail views of several multimedia documents is recommended. The requirements are stressed by the statements and behavior of the subjects. Twelve of them suggested having the ability of customization, like resizing. The next and previous buttons to switch between detail views of the complete list of results are suggested by seven users. The requirement for scrolling through the multimedia document was directly expressed by two users; also two suggested adding the search inside feature within the detail view. One explained the jump navigation between highlighted keywords within the texts of a multimedia document. Thereby a user can jump back and forth between highlighted keywords which fit to the initial query. Thus, a user is able to find relevant passages quicker, without engaging the search feature first.

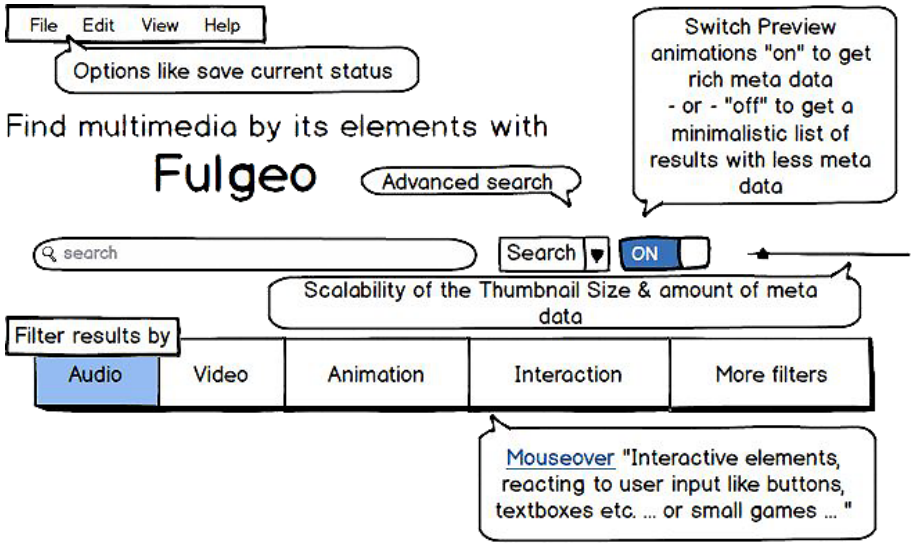
5.5. Request for New Features

Common browser-based features like a top menu bar, e.g., to save search sessions, a back-button, a right-click menu, should be added. One participant suggested a function to store the last search queries, settings, and result sets. Another user suggested including gesture interactions either by mouse movement and keyboard shortcuts for browsing the interface, or with regard to the rising mobile device usage and their ability of multi-touch gestures. Suggestion made by three other users were about being able to customize the order of result items, probably moving them by drag and drop. Two users suggested to stack collect multiple detail views in order to search within these presentations separately. Besides the already mentioned requirements for additional features, a play-button for videos was suggested. Finally, it was quite interesting to observe that none of the subjects requested a query-by-example or query-by-sketch feature. In fact, all subjects said they disliked the idea of query-by-example techniques.

6. MULTIMEDIA SEARCH ENGINE MOCKUP

Based on the user study and the derived requirements (cf. Section 3, 4, and 5), we created mockups for a future search engine for multimedia content, which will then also consider the semantic integration of time, space and, interaction. Overall we can state, that there are no requirements for totally new functions, but known and proven functions will be combined to allow a user centered design of a multimodal interface. The mockup provides an overview of the result list and presents additional information for each single result such as an advanced search, more filters, customization with choosing amount of shown data and thumbnails sizes and menu options like storing the current status (cf. Figure 5). The search by media type sup-

Figure 5. Mockup for the multimedia search bar: with filters, customization settings for previews, and options. Described with quick tips on mouse hover.

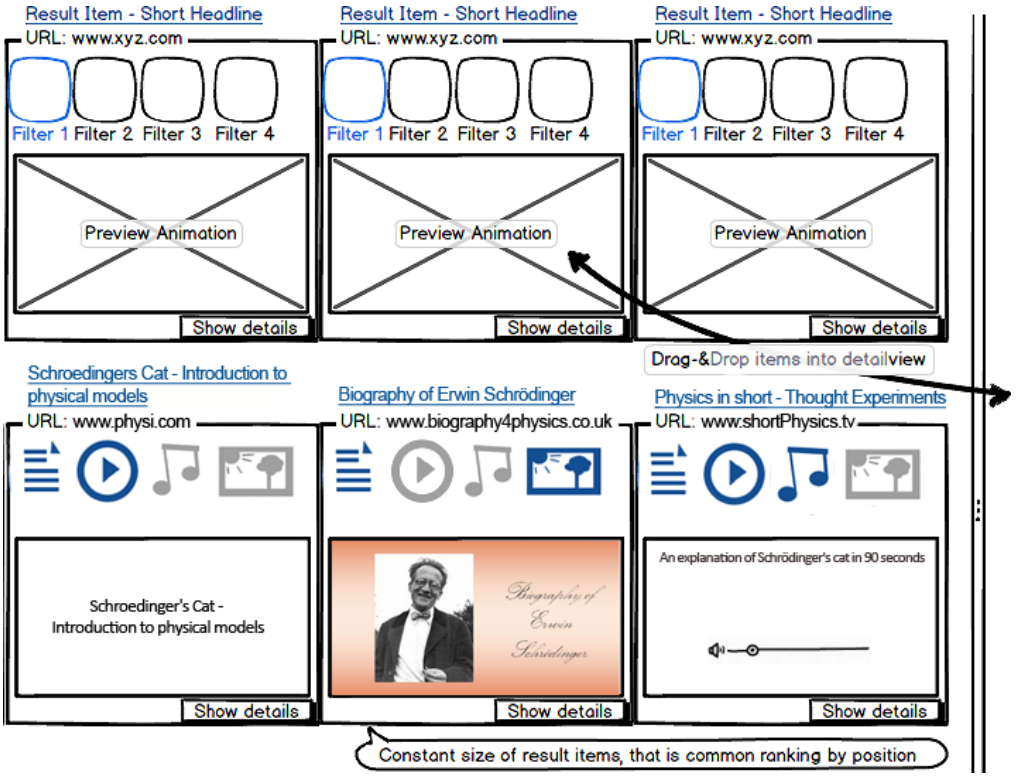


ports image, audio, and video. Additional filters for animation and interaction are added and explained when hovering over. The option for an advanced search is included in a dropdown list next to the textbox for entering the query. The advanced search enables to search for media in context, e. g. music, science, maps, or file type. The interface enables the users to customize the presentation of the result items, such as: changing scalability of the preview thumbnail and the amount of metadata by a slide control in line with the textbox. Another feature of customization is the button for activating or deactivating animations.

The results page enables users to view the result list by several aspects such as the overall relevance represented by the ranking position of the items, explicit headlines with a short and contextualizing sub-line (approx. snippets), a preview animation by mouse-over, metadata based on media type specifications, e. g., file size and duration, and metadata of common web content specifications, e. g., publisher, URL and release date (cf. Figure 6). The result list can be scrolled down to (in principle) infinity. Thus, no pagination is needed for users. The result view is divided into two parts: A vertical bar splits the list with the thumbnails of all relevant results from the detail view (cf. Figure 7). Using drag and drop one can move a document from the overview side to the detail view side. Alternatively, a user can also use the "Show details"-button below a thumbnail. The preview text is scrollable as most users expected it to be rich in quality. When the users scroll through the preview text, the animation of the presentation changes, too.

Likewise, when the play-button is pressed to render the presentation also the text below changes. This allows to search in the whole multimedia document and has a strong focus on the visual media types. The affiliated text, which changes accordingly, supports the search for visual media types and represents the relation of visual media types and text. A user is able to navigate through the result list via the detail view by clicking on the previous or next item buttons (cf. Figure 7).

Figure 6. Mockup showing the result list view with thumbnails presented in grid-layout, more metadata, and bigger symbols for different filters. The three items in the upper row illustrate a template for the result list view. The bottom row shows three concrete examples of multimedia presentations appearing in the result list.



7. DISCUSSION AND LIMITATIONS

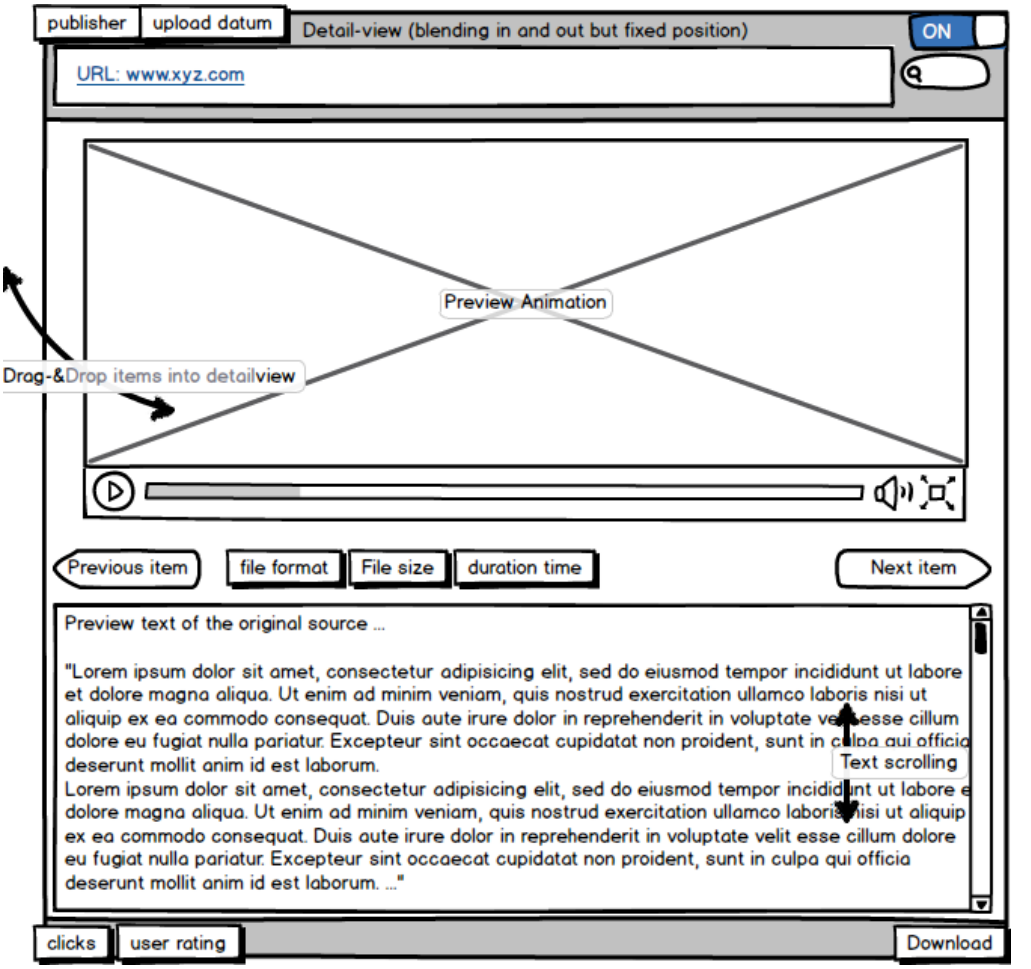
The purpose of this research was to gain insights into the requirements to a search engine or multimedia content. Based on these, we generated ideas for further research and development in the area of multimedia search and retrieval. Below, we reflect on the main insights gained from this study. In addition, we acknowledge aspects that are beyond the scope of this article and may be addressed in future work.

7.1. Discussion

Even though, the ergonomic quality of the prototype as assessed by users can be considered quite high, most users prefer a straight structure like a simple grid-layout of the result page in order to better orient themselves in the result list.

This is in particular important as naturally for a multimedia search engine the result set will be full of colorful animations. This insight is in line with findings of Lohmann, Ziegler and Tetzlaff (Lohmann, Ziegler, & Tetzlaff, 2009) who found out that fun and aesthetic aspects largely affect the user's interaction with, e. g., tag clouds or meaning. Tag clouds for example draw the user's intention to the center of the cloud or to colorful large tags, so that the user focuses less on content. A layout that is simpler might less influence the user's intention and encourage him in concentrating on the actual content. The subjects made clear that they did not want to have advanced features like query-by-example. This

Figure 7. Mockup of a more advanced detail view, showing the whole text, more metadata and allows for interaction like navigating through the multimedia content



finding is in line with the research by (Jaimes, Christel, Gilles, Sarukkai, & Ma, 2005) who states that in many real world applications it is hard to find an example to describe the user's information need. Many subjects asked for more individual filtering options which often referred to metadata like author, date of creation or the keywords given by the author, rather than technical differentiators such as the offered format filters for image, audio, video, and animation. Using filters supports the user in finding more relevant results to the initial query. If tags are shown next to the documents, which describe categories, e. g., persons or events, the user's assessment about the relevance of a document can be supported. This approach is inspired by Voxalead[2]. Altogether, the use of user generated annotations, comments, ratings, colorized tags etc. should be encouraged to enrich the metadata and include relevance feedback for the multimedia search (Jaimes, Christel, Gilles, Sarukkai, & Ma, 2005; Tjondronegoro, Chen, & Joly, 2008; Wang, Shih, Wu, Wang, & Jeng, 2011). Finally, it was interesting to observe that people do not have specific expectations to a multimedia search engine. However, they

like to be able to customize in which modality, context, and detail of the preview or thumbnail they are looking for multimedia content.

7.2. Limitations

The fact, that models in search engines often do not fit to the intentions of users (Kofler & Lux, 2009; Maniu, O'Hare, Aiello, Chiarandini, & Jaimes, 2013), implicates a need for more psychological research to build models of human activity during multimedia information search and retrieval, e. g., connected to common dual channel theories (Kahneman, 2011) or concrete versus abstract thinking (Trope & Liberman, 2010). The tendency to request customization of the search engine suggests that there is a higher level of perceptual gap between content and current representation of content in contrast to personal requirements of users regarding the representation of search results to estimate relevance of results (Jaimes, Christel, Gilles, Sarukkai, & Ma, 2005). Despite the results obtained from the study, the evaluation also needs to be seen in context of the methodological limitations based on self-report using a standardized questionnaire. Thus, after having implemented the mockups we plan to conduct a longitudinal study.

8. CONCLUSION

We evaluated the user interface of a search engine prototype for multimedia content with the goal to generate grounded ideas for further development in the area of multimedia search and retrieval. We found that users prefer straight layouts of multimedia result sets, but would like to switch between different modes of result set presentation with different amount of information. Also they would like to be able to customize the search engine by filters and search by context or domain. Based on the user study, we derived requirements and created mockups of a future multimedia search engine. In the next step, we will implement the requirements elicited in the study and conduct more extensive evaluations using subjects from different background and different knowledge levels.

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ENDNOTES

1 http://voxaleadnews.labs.exalead.com/, last access: 28/07/2014