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Author(s): Late, Elina; Ruotsalainen, Hille; Seker, Mert; Raitoharju, Jenni; Männistö, Anssi; Kumpulainen, Sanna

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From textual to visual image searching:

User experience of advanced image search tool

Elina Late[1[0000-0002-3232-1365]], Hille Ruotsalainen[1[0000-0002-2513-9223]] Mert Seker[1 [0000-0002-3837-8688]], Jenni Raitoharju[2 [0000-0003-4631-9298]], Anssi Männistö[1[0009-0008-3264-6726]] and Sanna Kumpulainen[1[0000-0002-7016-257X]]

[1] Tampere University, Kalevantie 4, 33100 Tampere, Finland

[2] University of Jyväskylä, Seminaarinkatu 15, 40014 Jyväskylä, Finland

Abstract. This paper reports findings from a study focusing on user experience of image search tool utilizing content-based image retrieval methods. Previous studies have indicated challenges in textual image search especially in the historical domain. As a part of the project, a prototype tool was created for searching digitized historical images based on their visual contents to provide support for user needs identified in earlier studies. The tool was tested by 15 experienced and novice participants who evaluated their user experience with User Experience Scale and by verbal feedback. Our results indicate that participants derived benefits from the search capabilities provided by the tool, which went beyond relying on textual image descriptions. However, problems occurred, for example, in evaluating the search results and in user skills. Results also emphasize the value of intellectually produced metadata for image searching and use. Therefore, future developments should focus on creating hybrid systems supporting both textual and visual image searching.

Keywords: Content-based image retrieval, digitiation, image archive, user experience

1 Introduction

Historical photographs form an important part of our cultural heritage capturing how the world looked like in the past. During the recent decades efforts have been put in digitizing photograph archives to make the contents available for various users. Indeed, digital image archives have become popular sources of historical information, for example, for scholars, information specialists, amateurs, and for the general public. For example, in history research images are important primary sources, and they are used for verification, documentation, or corroboration [1]. Although many digitized collections are openly available, access is often difficult because of the lack or incompleteness of image metadata [2,3]. However, textual metadata is vital since images are mostly searched using textual queries [4,2]. Yet, creating metadata manually is resource-

consuming and challenging as the same image may have varying interpretations, depending on the user's viewpoint. Also, previous experiences have demonstrated that information needs in humanities research can be highly diverse, making it difficult to create a single unified metadata scheme. Therefore, flexible systems are needed [5].

Content-based image retrieval methods (CBIR) have been proposed as a solution to the problem. These methods enable the recognition of people, objects, events, and landscapes within images, all without relying on textual metadata. Another valuable application of CBIR is reverse image search, which allows users to find images by uploading a sample image as a query. [24] Novel methods are already widely available in commercial image search engines, but cultural heritage collections often lack such functionalities because of limited resources in their maintenance and development. As some studies have shown, users are longing for new image search possibilities [7] others have argued that users have conflicting attitudes and needs for automatic methods [8]. In general, users value possibilities for searching conceptual attributes by querying and browsing [9]. However, image use varies according to the user's task and profession [10,2]. Nevertheless, there is a gap in research in this respect and we do not yet know how the users of historical photograph archives benefit from the recent developments in the automatic query.

This paper aims to fill this gap in knowledge by evaluating the user experience of an image search tool based on CBIR. As a part of our research project, a prototype tool was created for advanced image searching utilizing computer vision methods and machine learning models to identify searchable contents from the images. Our test collection included historical photographs from the Second World War many of which lack original metadata. The prototype was tested by experienced users of the original collection and by novices. User experience was measured using User Engagement Scale (UES) created originally by O'Brien, Cairns and Hall [11]. Additionally, user experiences were collected from verbal feedback during and after users tested the prototype.

Our research questions are:

RQ1. How satisfied are users with the advanced image search tool?

RQ2. What benefits and barriers do users see in content-based image retrieval?

This article will first provide a review of studies focusing on image archive use including search tactics, faced barriers, user needs and possibilities of CBIR methods. Next, we will introduce our research setting with the description of the prototype tool and the data collection and analysis. Finally, we present the findings followed by discussion and conclusions.

2 Earlier results on image archive use

Before building the prototype tool, the use of the digitized wartime photograph archive considered in this study was investigated in various ways. The original collection (FWPA, sa-kuva.fi) provided by the Finnish Defense Forces contains in total almost 160.000 photographs captured by photographers who served in Information Company troops in 1939-1945. The search is based on textual metadata of the images that were

mostly created during the wartime by the photographers. However, metadata is partly missing because of the chaotic times during the photography. Our earlier results provide a broad view of the search practices, barriers of use and information needs of the archive users. Next, the main results are presented and discussed with related studies on image searching and use.

2.1 Image search tactics

First, a survey data was collected to investigate the search tactics, user experience and success of searching by serious leisure users [9]. Results showed that users most likely preferred metadata-based keyword searching although filtering and browsing were also used. Other studies have also shown keyword searching to be the prior tactic for image searching within and beyond the history domain [12,13]. The participants gave high UES and varying search success scores for FWPA, but they were, in general, satisfied with their interactions [9].

Secondly, interviews with various user groups of the collection were done to get more in-depth insight of the use practices, barriers of use and information needs from various user groups. A study focusing on image use behavior of historians showed that the users most often combine various search tactics including keywords, filtering and browsing for image searching [2]. Keyword searching alone was an appropriate tactic only when the searcher had specific knowledge about the specific image (i.e., ID number). Browsing was included in most cases when searching for images, but typically used in combination with other tactics, as alone it was too time-consuming. Other studies have shown that browsing is used for broad and abstract searches or for serendipitous discovery when looking for inspiration [1,14,15,16,17]. However, the functionalities of the search interface influence users' browsing behaviour and is encouraged, for example, by providing images in categories [18,19].

2.2 Barriers and needs for searching images

Earlier study has also investigated the perceived barriers of using the archive. The interviewed archive users witnessed the lack, incompleteness, and inaccuracy of image metadata being the most serious problem for searching the images [2]. Also, a literature review by Cho et al. [4] indicated the typicality of semantic problems in image search. These problems relate to the terminology or language used in image retrieval systems. Textual searching requires image metadata that may be incomplete, do not meet the user's needs, and is expensive to produce because images always contain more information than can be produced by textual descriptions. [20,21]. Developed vocabulary and ontologies can quickly become outdated as the user needs are contextual and dynamic. Therefore, they require maintenance and upkeep [22].

Another paper focused on user desires for the image collection in the contexts of tools, collection, and socio-organizational issues [7]. Desires connected with tools were the most frequent, relating, for example, to the automatic annotation of the images, providing improved search options and developing the interface. Interviewees were intrigued by the possibilities CBIR techniques can offer, such as automatic character

recognition. Before Beaudoin [8] have argued that scholars in archaeology and art history were not interested in CBIR systems but wanted to rely on textual descriptions. Furthermore, desires related to the collection were related, for example, to improving the image metadata and the quality of the digitation. Socio-organizational desires were related, for example, to the need for new research methods in the historical domain to utilize images as research data [7].

The users' conceptual and descriptive image needs were also analysed [7]. Conceptual needs were the most frequent and included identifying specific persons, objects, or animals or their attributes within the images. Conceptual needs also included location/place, event/action, expression/emotion, and time. Regarding descriptive attributes, users expressed the most interest in descriptive information about the images (e.g., date), composition, external relations, color, image type or visual elements. These needs were mostly in line with an earlier study by McCay-Peet and Toms [23]. Studies have not found any significant differences in desired access points according to the use purposes [7,23].

2.3 Content-based image retrieval

User tagging and CBIR techniques have emerged as solutions to address the challenges associated with image retrieval. CBIR methods have already proven their effectiveness in recognizing various elements within images, including people, objects, events, and landscapes. Furthermore, newer advancements in CBIR can even identify photographic arrangements, such as the distance between objects, camera orientation, and the recognition of main characters. These capabilities have significantly expanded the possibilities in image analysis and retrieval. In addition, CBIR techniques also enable functionalities like reverse image search and the identification of similar images to those already found based on different image features or semantics. [6, 24, 31].

However, it is important to acknowledge that user studies play a vital role in determining the real-life needs and preferences of users. A study conducted by Beaudoin [8] revealed that while CBIR methods were found useful by users interested in formal characteristics like color, shape, composition, and texture, they did not cater well to users interested in known-items, themes, or locations. Although CBIR methods have developed since the study, it highlighted the significance of text-based retrieval of images for archaeologists and art historians, underscoring the importance of understanding user needs and preferences.

Furthermore, the adoption of novel methods for digital archives, including CBIR techniques, may face challenges due to limited resources. Cultural heritage collections often encounter resource constraints, which can impact the implementation of advanced technologies for accessing the contents [2]. However, developing the methods is crucial for organizations maintaining large image collections.

3 Research setting

3.1 Advanced Image Search Tool

As a part of research project Advanced Image Search Tool (AIST) was developed for accessing digitized photographs. We tested AIST on photographs captured during the Second World War in Finland. For our sample collection, we selected 23 800 images from the FWPA covering roughly a one-year period from October 1942 to September 1943 including every season of the year to have as much variation as possible in terms of, e.g., outdoor conditions and people's clothing. Our sample archive also includes 3800 images without any kind of original metadata or captions.

Based on the information collected during previous studies [2,7,9], AIST was designed to provide an easy-to-use implementation for many aspects of Automatic Image Contact Extraction [24] by applying different computer vision methods and machine learning models trained on large publicly available datasets. The search tasks can be conducted using a graphical user interface (Fig. 1). The tool is publicly available at GITHUB [25].

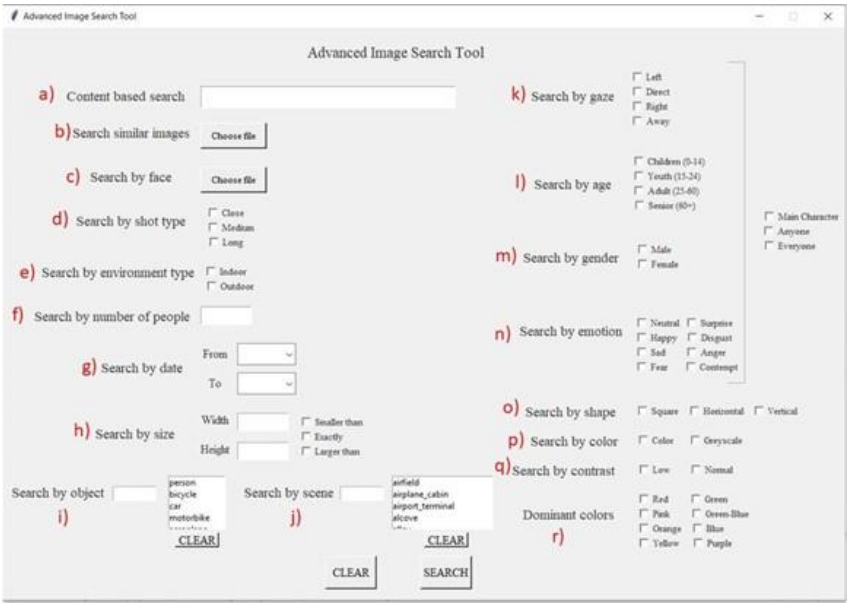

Figure 1. Screenshot of the user interface for AIST.

AIST allows various automatic content-based search types ranging from low-level features, such as color distribution, to higher-level semantic information, such as environment or objects, using search options (d-r in Fig.1). As image archive users emphasized the importance of analyzing people and objects from the images (Late, Ruotsalainen & Kumpulainen, 2023b), several AIST search features are also related to

people: their amount, gaze direction, age, gender, facial expression, and gaze direction (f, k-n in Fig.1). Different combinations of search features can be freely used. It is also possible to provide a query image and then AIST to retrieve images with similar overall features (Fig.1-b) or images with a similar face (Fig.1-c). Finally, it is possible to do text-based searches (Fig.1-a). Here it should be noted that the text-based search does not use the original manually entered captions, but the descriptive text used in the search is also automatically generated by different machine learning approaches.

3.2 Data collection and analysis

We invited in total 15 participants to test the prototype in May-June 2022. The participants were recruited partially from the previous interviews and partially through the contacts of the research group. The participants were either experienced users (N=8) of the original collection (researchers, museum curators, journalists, war history enthusiasts) or novices (history students N=7). The tests were audio and video recorded and the participants' consents were collected. One test session took approximately 45 minutes ranging between 20 minutes to 70 minutes.

Before the tests, the participants received an introductory PDF-document via e-mail. The document contained a description and guidelines for using different search features of AIST and a detailed description of the test situation. Before the actual testing, two pilot tests were run in order to test the operational readiness of AIST, the difficulty level of the search tasks, and to find out how much time is needed to perform the tasks.

The tests were conducted remotely via Zoom connection. The protype was installed on the computer of the researcher and the participants used it via Zoom. The restrictions caused by the COVID-19 situation that took place during the study did not allow us to gather the data face-to-face. When the tests started, the respondents were asked to select "Ask for Remote Control" from the Zoom interface. After the researcher approved the request, participants had access to AIST and were able to use the system themselves. First, the different features of AIST tool were introduced to the participants. After this, the users were asked to conduct five predefined tasks with AIST. The search tasks were formulated based on the actual searches that emerged in the previously collected interviews. This procedure followed the guidelines by Borlund [26]. The predefined tasks were used to ensure that all the participants were exposed to the different functionalities of the system. The respondents were asked to talk aloud while searching.

After completing the search tasks the respondents were asked to answer a short post-test questionnaire, which was based on the UES short form [11] to measure the user engagement in four factors presented in Table 1. The scale consists of 12 statements evaluated with a five-point Likert scale; Strongly disagree, disagree, neither agree nor disagree, agree, strongly agree. We translated the UES into Finnish. We also added one question from the UES long form to measure utilitarian achievement (UA) by asking to evaluate the success of the search task with the system. After completing the survey, the respondents were asked informally how they felt about using AIST, if they would recommend it to others and whether it would be useful for themselves. All discussions were audio recorded and transcribed into text.

Table 1. Questionnaire items measuring the user experience (UES) [11]

Focused attention (FA)	I lost myself in this experience
	The time I spent using the tool just slipped away
	I was absorbed in this experience
Perceived usability (PU)	I felt frustrated while using this tool (scores reversed)
	I found this tool confusing to use (scores reversed)
	Using this tool was taxing (scores reversed)
Aesthetic appeal (AE)	This tool was attractive
	This tool was aesthetically appealing
	This tool appealed to my senses
Reward factor (RW)	Using the tool was worthwhile
	My experience was rewarding
	I felt interested in this experience
Utilitarian achievement (UA)	I consider my experience a success

We analyzed the data using SPSS and Atlas.ti. First, we created five computed variables to evaluate the user experience (FA, PU, AE, RW and UES total). Because some of the questions were negative and some positive, the scores were reversed if needed. UA was analyzed separately. We studied the differences between experienced users and novices by comparing the means between the two groups (independent samples t-test). We also studied the correlations between UA and UES variables using Pearson bivariate correlation. Second, we uploaded the discussion transcripts into Atlas.ti where verbal expressions of user experiences were identified and coded. Quotes were further coded according to the categories used in UES scale (FA, PU, AE and RW). Illustrative quotes from the data were chosen and loosely translated from Finnish to English. Analyses were done by one researcher, but the codings were discussed in detail with another researcher in several rounds during the analyses process to reach a consensus.

4 Results

The image search tool gained an overall good evaluation by the test users with the user experience scale resulting an average 3.8 with 5 being the highest value. The scores of the four subscales varied (Fig. 2). However, there were no significant differences between the mean scores by experienced and novice users.

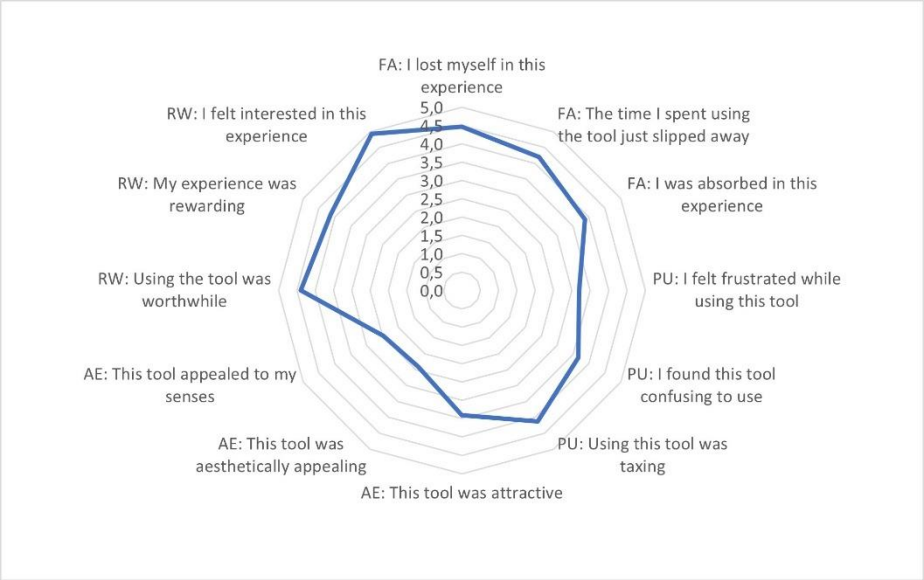

Figure 2. Mean scores from the 12 UES items

Out of the five measures, the Reward Factor was scored the highest (mean 4.6). RW consists of three items measuring the experiences of success and reward when using the system. The scores show the users found the experience interesting (see RW upper left-hand side Fig 2). In their verbal feedback, the participants discussed the future possibilities of the tool and visioned the tool being even more rewarding for bigger collections. The participants described the tool as supportive, enabling them to overcome the shortcomings of the image metadata and access the images beyond the textual descriptions. They found the tool showing the full potential of the collection providing also more opportunities for research use such as data analysis.

It brough up new ways of searching the contents and interesting images. It was also very rewarding to find those I haven't seen before and it allowed me to get familiar with the collection better. I was surprised when I realized how it finds new things. It is very different compared with the current system. But in a positive way. P10

This is the future and I really look forward this to become more common so we could utilize the full potential of the image data. Textual searching limits it a lot. P6

Focused attention (FA) was measured with three items focusing on users' experiences absorbed in the interaction and losing track of time (See upper right-hand side Fig 2). The mean score for FA was 4.3. In their verbal comments, the users expressed feelings of happiness, excitement, and fun. These feelings were raised by discovering new photographs from the collection and realizing the potential of new methods for retrieving the images.

Very pleasant and exiting experience and you suddenly see different and versatile images of certain era, yes it is inspiring. P13

Perceived usability measured the negative affections experienced as a result of the interaction with the system and the degree of control (see PU lower right-hand side Fig. 2). The mean score received for PU was 3.7. In the verbal feedback, various problems were brough up, many of them relating to unsuccessful searches and the lack of possibilities to evaluate the search results. Some users talked about the ”black box” effect as they did not understand how the system produced the results. This resulted in feelings of insecurity and lack of trust. According to the participants, using the tool for research purposes demands a clearer understanding of the system. When collecting images used as research data, the scholars had a need to understand what the search was based on. Thus, the tool should be formally documented and evaluated for future development.

I wonder how many relevant images I am missing…the search and results seems to be quite random. If I search with “music” I get nothing, but when I search with “playing music” I get loads of images. P2

The problem is, if I use this tool for my research, I should see the algorithm that this is built upon. At this stage it is too laborious and uncertain compared with the results it gives. P14

The users hoped for more support and guidance from the system for making the searches as they did not know, for example, what words they should use for querying. Searching images by visual contents demanded a new approach also from the users.

There should be a list available what words it can recognize and what words it has learned. It was frustrating not to know. P5

In addition, only features relevant for the context of the collection should be available. The prototype included, for example, a list of activities that could be used for searching, but as this was a ready-made list, all activities did not made sense for this specific collection. Many participants agreed that the old and the new systems should be integrated to allow users to utilize the best features from both approaches (original metadata and content-based searching).

It would be good if these two were combined. This and the captions. P12

Furthermore, users reminded that providing access to the images does not necessarily remove all the problems in using them. For example, using images for illustrating books requires trustworthy contextual information about the image. The tool cannot derive this information solely based on the the image analyses alone.

Aesthetic appeal factor measures the attractiveness and visual appeal of the interface with three items (see AE lower left-hand side in Fig. 2). The mean score for AE

was the lowest compared with other factors totaling 2.8. Indeed, in their verbal comments, users agreed that the visual appearance of the prototype was not aesthetically pleasing but at the same time adding that their expectations for not-for-profit services were not similar as for systems by big corporations. However, participants brought up that the visual design should support the user better, for example by selecting colors guiding the user.

> *I don't have any requirements for the interface, but let's say this would be a service with millions of users, then you would probably want this to look more polished. P3*

> *There could be certain colors for certain functions to help users to remember "Yes, that I was supposed to click". P1*

Additionally, we asked if the users were able to find the images they were searching for with the system (UA). More than one fourth (26.7%) agreed and 60% partly agreed with the statement. There was no variation between the experienced and novice users in the UA score. The UA factor correlated significantly only with the PU factor ($r = .577$, $p = .024$). The users successful with searching had fewer negative experiences compared with those experiencing a lower rate of success. In their verbal feedback, the experienced users were able to compare their experiences with the old system and the prototype in following way:

> *This is interesting and for sure there are possibilities, but for now it feels unfinished. Some results don't match with my search and on the other hand it doesn't find all photos from the collection. P7*

5 Discussion

The aim of our study was to analyze user experiences on a CBIR tool. As CBIR methods have been seen as a solution for problems of lacking metadata for textual searching of historical images, there is a lack of recent studies of the usefulness of such systems for the actual users [7,8]. As a part of our project, a prototype tool was created for searching images from historical image collections to provide support for user needs identified in earlier studies [2,7,9]. The tool was tested by 15 experienced and novice participants who evaluated their user experience. Our results indicate participants having high expectations for the tool but experiencing some difficulties when using it.

Our first research question was: How satisfied are users with the advanced image search tool? Overall, the study participants were very satisfied with the image search tool when evaluated by the UES. The aesthetic appeal of the tool was scored the lowest, although the users did not have high expectations for the prototype looks and the aesthetic appeal was not prioritized in the development. We did not observe any significant differences in UES scores between experienced and novice users. Surprisingly, the scores were also very similar compared with to scores given by serious leisure users of

the original interface for the same collection [9], although the tool tested this time was a prototype. However, more studies with larger samples are needed to cover the variety of CBIR based tools to provide more reliable results of the user experience. Also, comparative studies on different user groups are needed as Beaudoin [8] observed differences in user needs. Nevertheless, this study provides a good starting point for future research.

Secondly, we asked: What benefits and barriers do users see in the content-based image retrieval? Our results show that CBIR has much to offer for searching the contents from historical image collections with limited metadata. Most participants were excited about the possibilities of the novel methods and described such tools as being the "future". With the prototype tool the experienced participants could already find images they had not found before from the collection. Indeed, earlier studies have showed that users desire CBIR methods and experience the lack and incompleteness of metadata as a major barrier to accessing the images [7]. CBIR systems may be helpful also for searching known items as before this has been frustrating for users lacking information of the specific image [2]. Another benefit of CBIR is overcoming the limitations caused by the language of the captions [13].

However, for professional use AIST should be further developed, evaluated and documented. Users value and expect transparency in use, ability to evaluate search results and clear guidelines for use. CBIR based tools demand new approaches also from the users. Before they have tried to imagine what words the original photographer may have used for describing the image [7], but with the CBIR they need to learn to think about the contents of the image and how the tool might interpret them. Thus, future research should focus on search behaviors in real-life activities to find ways to support the information seekers with AI tools. Additionally, user training is needed.

Although new functionalities were appreciated, users want to also keep the features of the original search tool. Because, for example, the location, time and name of the photographer are among the most important access points for images [7], automatic metadata creation cannot totally replace the original metadata. Original captions also have their own value for image use in addition to accessing them [1,2]. Historians place significant importance on the trustworthiness associated with reputational institutions, such as archives, and the provenance of photographs when utilizing them for their research. They value original descriptive information, including captions, keywords, subject headings, the original medium of the photographs, and even details like the image size. While there are cases where digital surrogates cannot fully replace the original paper photographs, historians recognize the value of digital collections as a tool for searching the images. [1] This applies also to digitized textual materials [27,28]. Our participants also reminded us that providing access to the images does not solve all the problems in using them. Many images lack metadata that is crucial for interpreting the contents. When gathering research data, scholars need information, for example, about the aboutness of data, characteristics of data, metadata, and secondary information about data [29] that CBIR is unable to produce. More metadata could be produced intellectually by allowing users to annotate content directly and integrate knowledge from different sources into the collection.

Therefore, new features and search possibilities should be built on top of existing systems or earlier functionalities should be integrated with the new ones to create hybrid systems [8]. Different metadata types could be provided as layers on top of the original metadata and let the users decide which to use. Developing cultural heritage collections requires both financial and intellectual resources to ensure the continuation of the digital curation [30]. Keeping on track with developments offered by commercial systems is not easy for publicly maintained services but it is crucial to provide access and support for various user groups and differing uses of the collection. Collecting real-life user experiences and use practices of digital tools is crucial also in future research to ensure their evidence-based development.

We conducted user tests for collecting user experiences about the prototype tool for searching historical images. However, our data contains experiences only from 15 users and from one tool. To more fully understand the user experiences and perceived benefits and barriers with CBIR tools beyond the service level, there is a need for more realistic research settings, such as longitudinal ethnographic research, to capture real-life information interactions beyond a single system. Additionally, the tool should be evaluated in a task-based manner with focusing on different search options of the system. Our current method provides feedback on the overall experience.

Data for this study was collected remotely. However, based on our experience, online environment was convenient for testing the system. Zoom application was mostly well-known by the research team and the participants, and audio and video data were easy to record with Zoom. The ability to use "Ask for Remote Control" functionality in Zoom was a good solution for testing. Online tests were also easy to organize as the participants did not need to travel to the research site. This saved time and resources. Problems that occurred during the tests were mainly minor issues with internet connections and Zoom usability. In some cases, internet connection was unstable but luckily the connection lasted throughout the test.

6 Conclusions

Searching images from digitized collections has been troublesome because of the limitations of textual querying. CBIR methods have provided solutions for overcoming the problems caused by the lack of metadata. This paper investigated the user experiences of an advanced image search tool for finding historical photographs based on their visual contents. The user experience of 15 test users was measured using the UES. Our results show that users perceived the tool as useful for searching the images beyond image captions. However, users had difficulties in evaluating the search results as they did not fully understand how the system worked. Indeed, CBIR based tools demand a new approach and skills from the users and user training is needed. Furthermore, users were not willing to replace the old search system with the new one but rather hoped for hybrid systems including the functionalities from visual and textual search methods. Trustworthy metadata is also evident for image use. Future research is needed to better understand the search behaviors in real-life activities to find ways to support various image seekers with CBIR based tools.

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