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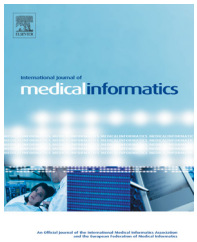

User-oriented evaluation of a medical image retrieval system for radiologists

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ABSTRACT

Purpose: This article reports the user-oriented evaluation of a text- and content-based medical image retrieval system. User tests with radiologists using a search system for images in the medical literature are presented. The goal of the tests is to assess the usability of the system, identify system and interface aspects that need improvement and useful additions. Another objective is to investigate the system's added value to radiology information retrieval. The study provides an insight into required specifications and potential shortcomings of medical image retrieval systems through a concrete methodology for conducting user tests.

Methods: User tests with a working image retrieval system of images from the biomedical literature were performed in an iterative manner, where each iteration had the participants perform radiology information seeking tasks and then refining the system as well as the user study design itself. During these tasks the interaction of the users with the system was monitored, usability aspects were measured, retrieval success rates recorded and feedback was collected through survey forms.

Results: In total, 16 radiologists participated in the user tests. The success rates in finding relevant information were on average 87% and 78% for image and case retrieval tasks, respectively. The average time for a successful search was below 3 min in both cases. Users felt quickly comfortable with the novel techniques and tools (after 5 to 15 min), such as content-based image retrieval and relevance feedback. User satisfaction measures show a very positive attitude toward the system's functionalities while the user feedback helped identifying the system's weak points. The participants proposed several potentially useful new functionalities, such as filtering by imaging modality and search for articles using image examples.

Conclusion: The iterative character of the evaluation helped to obtain diverse and detailed feedback on all system aspects. Radiologists are quickly familiar with the functionalities but have several comments on desired functionalities. The analysis of the results can potentially assist system refinement for future medical information retrieval systems. Moreover, the methodology presented as well as the discussion on the limitations and challenges of such

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studies can be useful for user-oriented medical image retrieval evaluation, as user-oriented evaluation of interactive system is still only rarely performed. Such interactive evaluations can be limited in effort if done iteratively and can give many insights for developing better systems.

1. Introduction

Images are an essential part in medical diagnosis and treatment planning. They are produced in quickly increasing quantities and also in with an increasing variety. Radiologists are often overloaded with the large amount of diagnostic images produced in hospitals that need to be read, and the ever-increasing number of image details (thin slices, temporal series, higher resolution) can put stress on the radiologist due to information overload. This creates risks to miss important structures or potential problems in the images. The medical literature often available on the Internet is also an important resource of visual medical information. However recent studies report that search for radiology images fails one out of four times [1]. The rapid growth of visual information available both in variety and quantity dictates the need for systems that facilitate quick access to relevant information. Medical information retrieval systems need to be able to handle real information scenarios in order to have an impact in radiology.

Much of the knowledge stored in images is little exploited at the moment because direct access to the visual image information (that is, the information that is contained in the visual content of the image represented by visual features) is rarely possible. Content-based image retrieval (CBIR) uses the visual content (such as shape, color and texture) of images or image regions as positive and negative examples to retrieve other images or cases that are related. Over the past 15 years, CBIR has been considered promising for assisting information search in the medical field and several systems have been developed [2–6]. However, most systems were rather technology-driven and very few applications have reached the end users for routine use or were integrated into the clinical workflow [7].

User-centered design (UCD) [8] has been used for several decades in industry [9,10], but also in medical applications [11]. A few aspects of UCD have also been used for CBIR [12]. The concept behind this approach is to guide a system's design and development by investigating use case requirements and user feedback to improve the product's usability and the user experience. The key elements of UCD are described in the ISO (International Standardization Organization) standard for the human-centered design for interactive systems (ISO 9241-210, 2010) [13].

The first step in UCD of software applications includes investigation and understanding of the user requirements in order to identify the general design directions [14,15]. User-centered evaluation is an important part of UCD in the early stages of the development [16] and needs to be seen as an iterative process throughout the development cycle [10,11].

The assessment is often performed in the form of empirical usability tests in a number of target users to interact with the system in a lab environment or in a natural setting. Usability of the system is assessed with factors such as learnability, efficiency, effectiveness, memorability and satisfaction [16]. A survey on common usability testing techniques and tools is presented in [17]. The main methods for conducting such tests include thinking aloud execution of tasks, direct or recorded observation of the interaction, survey forms and log analysis. A more detailed description of aspects that need to be taken into account when designing a usability test is given in [18].

The number of users required for conducting user tests is another important aspect when designing a usability test. Early studies have reported that a single individual is not able to detect all usability problems but that 3–4 users are sufficient [19]. In [20] it is suggested that 5 users are enough, while other studies disagree, highlighting the need for larger user tests [21] [22]. The exact number of participants remains an open question, though in [23] it is proposed that 5 participants are indeed enough for each iteration of an iterative user-centered evaluation.

In this article a round of the user-centered evaluation of the Khresmoi[1] search engine is presented. This system aims at assisting general practitioners, the general public and radiologists in accessing trustable biomedical information. These three target groups have different search behavior, goals and information needs. Thus, the system is divided into subsystems, designed to correspond to the requirements of the target groups. Following the same concept, usability tests were designed and conducted separately, concentrating on domain-specific research questions.

This study focuses on the tests of the 2D image search prototype of the Khresmoi system that is designed to be used by radiologists. The system combines text and CBIR search for finding and navigating through scientific biomedical articles and the images they include. The prototype design is based on the investigation of the image use behavior of radiologists [1]. The backend of the system is based on the Parallel Distributed Image Search Engine (ParaDISE) first used in [24] and the front end uses the ezDL interface [25].

The general research questions that the evaluation tries to answer are:

- Does the Khresmoi system improve current search for information in radiology (which is mainly patient-centered or using Google on the Internet for general information needs)?
- Does it cover finding answers to unmet information needs and to what extent are these covered?

[1] http://www.khresmoi.eu/.