Human-computer interaction in radiology

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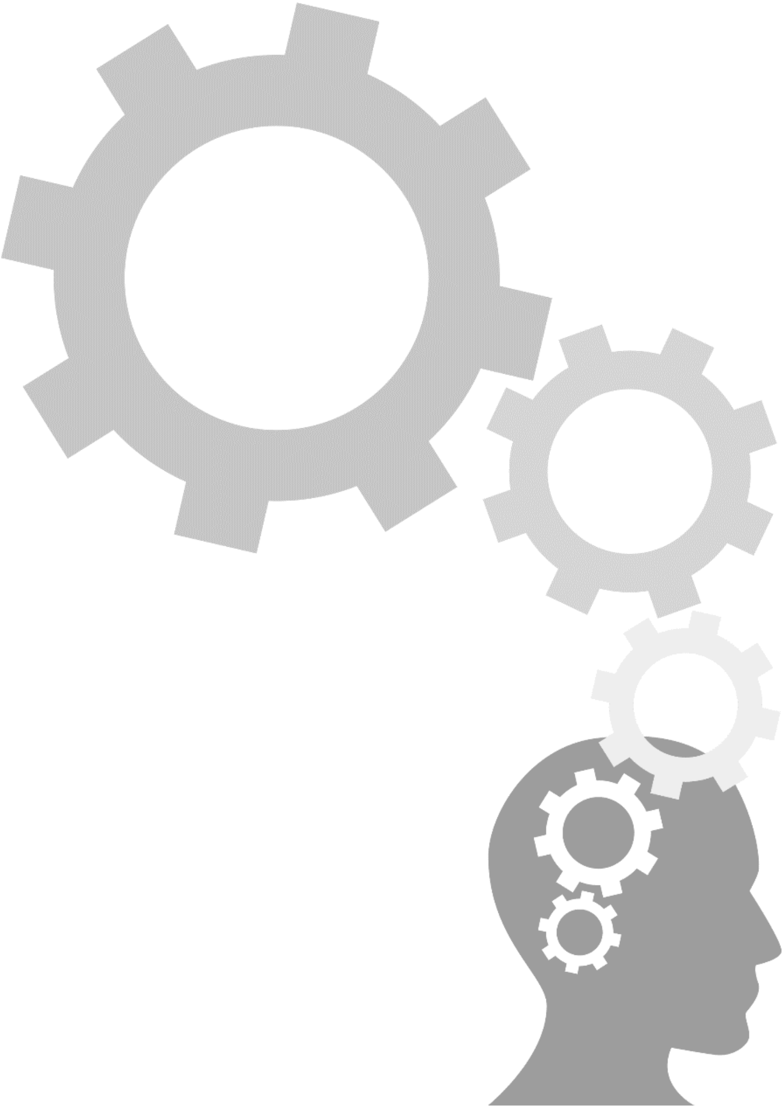
General introduction



Radiology is a medical specialty that uses medical imaging technology to judge the anatomy and pathology of structures in the human body. Since radiology is fully dependent on technology, it is no surprise that it was among the first medical specialties to embrace the digital revolution.

Today, digital technology pervades the radiology department. The workflow of the department is managed by a Radiology Information System (RIS), medical images are stored and distributed by a Picture Archiving and Communication System (PACS), they are viewed on a computer workstation where they can be manipulated by advanced image processing algorithms, and diagnostic reports are dictated using speech recognition software.

This means that the job performance of today's radiologists is determined to a large extent by how well they can interact with computer systems. It is therefore vital that the user interfaces through which this interaction takes place are of high quality, and allow radiologists to perform their jobs with maximal effectiveness, efficiency, and satisfaction. As digital technology evolves, and the complexity and diversity of computer systems with which radiologists interact increases, the quality of this interaction becomes even more important.

In this thesis, we aimed to study the interaction between radiologists and computer systems, and to identify ways to improve the quality of this interaction. We focused on usability evaluation, interaction techniques, user interface customization, computer-aided diagnosis, and structured reporting.

Usability evaluation (Chapters 2–4)

Usability is the effectiveness, efficiency, and satisfaction with which users can use a system to achieve their goals in a specific context of use [1,2]. Since interacting with computer systems has become an integral part of the radiologist's job, it is vital to ensure that these systems have high usability.

In Chapter 2, we performed a usability test of four different PACS workstations. The PACS workstation allows radiologists to retrieve, view, and manipulate images, and plays a crucial role in the radiological workflow. We aimed to compare the usability of the PACSs, determine whether a usability test has added value with respect to the traditional way of comparing PACSs based on functional requirements, and to evaluate the appropriateness of a task-based methodology for a PACS usability test.

In Chapter 3, we evaluated the usability of a radiology workstation consisting of an image viewer (a client for the PACS), a workflow manager (a client for the RIS) and a report editor with speech recognition, after it was deployed in a hospital. We aimed to determine the number, nature and severity of usability issues radiologists encounter while using this workstation in clinical practice, and to assess how well the results of a pre-deployment usability evaluation of this workstation generalize to clinical practice.

In Chapter 4, we introduce a novel usability evaluation method: analysis of user interaction logs using a data mining technique called closed sequential pattern mining [3,4]. This method was used to perform a post-deployment usability evaluation of a PACS client, and its effectiveness was compared to the method used in Chapter 3.

Interaction techniques (Chapter 5)

An interaction technique is a way of using physical input/output devices to enter information into a computer [5,6]. Interaction techniques are the building blocks of the user interface and are therefore important in the human-computer interaction.

In Chapter 5, we implemented four touch-based interaction techniques for I2Vote [7]: an image-based audience response system for radiology education in which users need to accurately mark a target on a medical image. In order to determine which technique would be the most appropriate for I2Vote, we performed an empirical study in which users marked a target on an image using all four techniques on either a smartphone or a tablet. The techniques were evaluated in terms of accuracy, efficiency, ease-of-use and intuitiveness. We also investigated how the different devices affected the performance of the techniques.

Although this study focused on the I2Vote system, the implemented interaction techniques could be used in any touch-based radiology computer system.

User interface customization (Chapter 6)

As in many other modern software packages, the number and complexity of functions in the radiology PACS client is very high and continues to increase. This poses the challenge of creating a user interface that presents these functions to radiologists in an appropriate way and allows them to interact with the software efficiently. Because different radiologists use the software in different ways, depending on their goals and interaction preferences, creating an interface that suits each radiologist is a difficult task.

As a solution to this problem, most PACSs have an adaptable interface, which allows radiologists to customize several aspects of the PACS according to their personal needs and preferences. However, previous research has shown that users often do not customize effectively [8] or they do not customize at all [9]. This means that they will never interact with the system in a maximally efficient way.

In Chapter 6, we developed a system that generates user-specific customization support based on users' function usage. The support was designed to help users customize the PACS effectively. An empirical study was performed to determine whether this adaptive customization support would be a useful addition to an adaptable PACS interface.

Computer-aided diagnosis (Chapter 7)

Computer-aided diagnosis (CAD) systems use image processing and artificial intelligence techniques to detect and/or evaluate abnormalities in medical images. They aim to assist radiologists during image interpretation and thereby improve their diagnostic performance. Various studies have shown that radiologists and CAD can make an effective team that reaches a higher level of diagnostic performance than one radiologist alone (e.g. [10–12]).

However, the team performance of radiologist and CAD is lower than what might be expected based on the performance of the radiologist and the CAD system in isolation [13,14]. There are even studies that found no benefits of CAD on radiologists' diagnostic performance (e.g. [15,16]), an increased sensitivity at the cost of reduced specificity (e.g. [17,18]), or even reduced sensitivity of the best performing radiologists for difficult cases [19]. This suggests that the interaction between radiologists and CAD is not optimal.

An important factor in the interaction between humans and automated aids (such as CAD) is trust [20–26]. Suboptimal performance of the human–automation team is often caused by an inappropriate level of trust in the automation [26]. In Chapter 7, we examined the role of trust in the radiologist–CAD interaction and suggest ways to improve the output of the CAD system so that it allows radiologists to calibrate their trust in the CAD system more effectively.

Structured reporting (Chapter 8)

Radiology reports are normally dictated and constructed freely during the interpretation of the radiological images. However, structuring the information in the report is preferable from a data management and clinician's perspective.

To come to well-structured reports, structured reporting software has been proposed that lets radiologists to report in a (highly) controlled fashion. However, studies comparing structured reporting software to conventional free-text dictation have shown mixed results [27–31]. A major argument against reporting in a structured fashion is that it would require extra actions by the radiologist, which cost time and might interfere with the interpretation of the images [27].

In Chapter 8, we developed and tested a system that automatically converts dictated free-text reports into structured, standardized reports. Such a system would yield structured reports without the need for radiologists to change the way they construct their reports.

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