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Distributed Intelligent Learning Environment for Screening Mammography

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Introduction

In this paper we describe a computer based training system to support breast cancer screening. We examine the design constrains required by screening practices and consider the contributions of existing theoretical frameworks, of teaching and learning principles.

Mammography and Screening Practice

Breast cancer screening programmes invite women of a certain age group for regular assessment. They undergo an X-ray examination involving one or more views of each breast (called *mammograms*). These mammograms are, ideally, reviewed (independently) by at least two film readers. Readers compare current with previous films (where available) and identify mammographic features indicative of cancer. Film readers are aware of their responsibility both to detect cancers and to avoid recalling healthy women unnecessarily.

Although mammography provides an acceptable trade off between cost, sensitivity and specificity it is known to be an imperfect screening technique [1]. Mammographic appearances may be very small, faint and deceptive. Normal tissue may be perceived as an abnormal feature. In addition, malignant presentations may range from being mildly suspicious to distinctly malignant. Studies show that between a quarter and a third of visible cancers may be missed during screening [2].

Film Reading Expertise

Researchers have reported high variations in radiologists' performance [3]. Because of the complex interactions in screening, these results cannot be attributed to a single factor but variations in performance probably reflect variations in expertise and it seems likely that the acquisition of expertise requires planned and targeted training of a standard that is often unobtainable in practice [4]. Although film readers see on average about 5000 cases per year, on average only six cancers are found for every thousand women screened. A trainee who learns by working alongside an expert colleague could read films from 200 cases a week for six months and see as few as thirty cancers.

Textbooks and mammography atlases are commonly used to support training and computer-based training systems (CBT) are expected become an integral part of radiological training, giving users access to a much greater range and variety of images and to learn from them in ways that can be fitted into a busy clinical schedule.

Designing a Computer Based Training System for Screening Mammography

In mammography the design of CBTs has been determined by the practical needs and rarely guided by educational theories or pedagogical principles. The underlying learning goals (*what* the system will teach) and teaching strategies (the *ways* in which the system will teach) of CBTs are reflected in the way the information is presented in the course of a training session. Most attempts to provide such a tool have, however, been based on relatively modest image databases, and offer a limited educational experience.

We wish to explore the long tradition of research into applications of artificial intelligence in educational software, more specifically, the design architectures of intelligent tutoring systems (ITS) and intelligent learning environments (ILE). These two approaches explore the design of intelligent systems to support learning - *what* (knowledge domain), *who* (view of the user) and *how* (teaching strategies) - in different ways.

ITSs are based on the cognitive theory of skill acquisition and incorporate a number of instructional principles (multiplicity, activeness, accommodation and adaptation, and authenticity) and methods (including modeling, coaching, fading of assistance, structured problem solving, and situated learning) from this theoretical framework. Such systems follow an *objectivist* view of the nature of knowledge. The knowledge to be learned is pre-specified and transferred by communication or problem solving [5]. In contrast, ILEs follow a *constructivist* view, assuming that knowledge is individually constructed from what the learners do through interacting with an environment [6]. ILEs, therefore, contain knowledge about the context in which learning takes place and the activities in which the user is expected to engage, in order to provide a rich and flexible environment.

In screening, interactions are dynamic and complex and reflect the social nature of reading [7], involving activities such as discussion, monitoring, and the review of procedures and targets. Our field work has revealed that the important decision in screening, whether or not to recall a woman for further tests, is based on an intuitive assessment of the risks associated with each atypical appearance and the appraisal of that assessment in the specific context of each individual screening centre. This can not modelled in the way that the objectivist approach would require. The constructivist approach, therefore, seems more appropriate for screening. Translating its concepts to computational terms, our system allows for exploratory and experiential learning in which the user chooses different ways of doing things, reflects on the actions taken and the system, based on observation of the user's actions, suggest alternative pathways. In this way the system will fit the user without being prescriptive about what and how they learn.

We believe that the resources required to develop a CBT for screening mammography can only be obtained through collaboration. It is only by creating a network of students and mentors across different clinical sites that we can hope to obtain the breadth and variety of experience required to build robust models of the screening context.

We are developing a *distributed* ILE in which the work of collecting and annotating interesting cases will be shared and the experience of using the images will be pooled. The system will offer a number of benefits:

- **Availability** A digital archive of training cases will give instant access to a wide range of training materials, and thereby open up new opportunities for training delivery.
- **Completeness** An ILE can broaden substantially the range of cancerous presentations to which a trainee is exposed.
- **Automation** An ILE can automate aspects of the training process, for example, the marking of a trainee's decisions and tracking performance.

- **Collaborative Working** An ILE allows: remote delivery of training supervised by mentors in accredited training centre; support for 'asynchronous' supervision in centres where mentors and trainees are co-located; the opportunity for trainees to share their experiences regardless of whether they are co-located.
- **Statistical analysis** Aggregate statistics of performance on lesions, cases and training sets over repeated application by trainees with differing levels of experience will be used to provide metrics of 'difficulty'. These assist with the allocation of training sets commensurate with a trainee's current expertise, an accurate assessment of a trainee's performance and progress, and also with the compilation of new training sets to meet training goals and facilitate the learning of clinically important distinctions.

The prototype tool is based around a screening workstation, so that the training takes place within an environment that supports routine clinical work. Users have access to a large database of specially selected cases, including a mix of typical and unusual cases, both normals and cancers. The prototype allows users to select a training roller from a menu of cases with different characteristics, to attempt interpretation case by case and to receive feedback, both in the form of detailed advice about the interesting features of each case and through summary statistics of their overall performance. The difficulty of the tasks may be adjusted. The system also presents suggestions of areas that the user might wish to review again or to concentrate on, and would keep a record of what the user has done. In this way, the training system can induce users to reflect on strategy and plans.

Discussion and Future Work

Our work is carried out as part of a larger project [8] set out to demonstrate the benefits of Grid technology for breast imaging in the UK. Over the last two years team members have conducted lengthy observational studies of screening work and training sessions. Senior radiologists running national training centres have been closely involved in the design, from the very earliest stages. As a result the existing tool has a number of advantages. The environment is a good approximation to a high-quality digital screening workstation. The quality of the didactic information that the tool can provide is exceedingly high, being based on careful and scrupulous annotation of a large database of images by experienced radiologists with an interest in training.

In this poster we show how a detailed understanding of screening work influences the design of a CBT tool. Some aspects of screening are embedded in a context and therefore hard to formalise. Some of the knowledge used in screening is implicit in the process of reading and therefore easily overlooked. Using a pragmatic approach, we are designing a system to allow for exploratory and experiential learning. Such a design is more likely to succeed in a screening environment because the system will fit the needs of film readers without being prescriptive about how and what they should learn. We have looked at the contribution of ITS and ILE frameworks and highlighted the advantages of using the ILE approach, as well as the benefits of incorporating both approaches on the design of an intelligent learning environment for screening mammography. Our design will permit experiments to evaluate how users explore the available data; to collect data on user performance, skill and expertise; and on individual case difficulty and roller composition.

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