Generic Infrastructure for Medical Informatics (GIMI): The Development of a Mammographic Training System

Moi Hoon Yap, Alastair G. Gale, and Hazel J. Scott

Applied Vision Research Centre, Loughborough University,
Loughborough, LE11 3TU, UK
{m.h.yap,a.g.gale,h.scott}@lboro.ac.uk

Abstract. In the UK, a large-scale collaborative research project (GIMI: Generic Infrastructures for Medical Informatics) is underway which is concerned with the development of a secure IT infrastructure to support very widespread medical research across the country. One aspect of this project is to develop a training tool for potential use by mammographers in the UK Breast Screening Programme. A working prototype system has been developed which is currently being tested by clinical colleagues so as to enable it to be further developed prior to any wider deployment. This is currently based on knowing an individual's strengths and weaknesses in mammographic interpretation. The background to the project is given and then the ongoing research is detailed together with future plans for the proposed system.

Keywords: Grid-enabled healthcare, mammography, training system, breast screening, computer-based learning.

1 Introduction

Breast screening in the UK is a national programme involving 109 separate screening centres coupled with additional mobile screening vans which together annually screen some 1.8 million women a year [1]. The screening programme is now 20 years old and was initially targeted at 50-64 year old women and in 2003 the upper age was raised to 70 years. In late 2007 it was announced that screening was to be extended again to women aged 47 to 73 years by 2012. Virtually all screening is currently carried out using analogue film, with a small number of centres trialling computed radiology and also full field digital screening, full field digital mammography is also used in some centres for further investigations in following up screened women. It is planned that by 2010 every screening centre will have at least one digital mammography unit. Other research is underway to ascertain the best ergonomic approach for the introduction of widespread digital screening interpretation when the prior screened cases are in film format, which is a situation that for some centres will exist for several years [2]. Elsewhere in radiology virtually all imaging in the UK is filmless under the NHS Connecting for Health programme which is a national IT programme to introduce computer systems into the UK health service with the aim of improving both services and patient care. There are currently 127 PACS systems in England;

E.A. Krupinski (Ed.): IWDM 2008, LNCS 5116, pp. 577–584, 2008.

which have been employed in over 25.5 million patient studies generating some 640 million stored images. Breast screening has been outside such PACS systems but now various approaches are being investigated to integrate breast screening more into hospital RIS and PACS systems. The move to digital imaging in mammography means that different types of training delivery become possible; for instance using training utilising mobile devices [3].

GIMI is a Grid based project which addresses different medical domains such as diabetes and breast screening; with the latter being considered here. The aim of this project is to develop a training tool. To do this, the potential advantages of the Grid (accomplished by the GIMI middleware service interoperability framework (sif)) is used to facilitate the development of an intelligent tutoring system which accesses screening cases from geographically dispersed sources. The system has dual functions; auditing and training. Auditing permits the checking of both existing breast screening cases in the database together with new cases (prior to being accepted into the database) and ensures that these are described and annotated appropriately. Subsequently, these cases can be utilized for training. The tutoring system allows cases to be selected on several criteria, based on knowledge of the screening skills of the individual user.

2 Background

In the UK, all screening personnel involved in the NHS Breast Screening Programme undertake PERFORMS, an annual self assessment scheme [4]. Twice a year 560 individuals interpret carefully selected sets of recent difficult screening cases. In doing this they identify certain key mammographic features, as well as defining their location, and rate each case on whether they consider it to be normal, benign or malignant. Participants gain immediate feedback on their decisions as well as subsequently being able to see how they have fared as compared anonymously to all other screeners. An individual can rapidly gain insight into the level of their mammographic interpretation skills. Importantly, their skill in correctly locating and identifying key mammographic features represents their detection ability and the overall case decision, having correctly identified the key mammographic features, indicates their interpretation skill. Knowledge of such detection and interpretation abilities can then be used as an input to inform the subsequent structure of a training scheme for each person whilst still maintaining the anonymity of each individual's performance data.

Ideally any tutoring system requires a large cohort of suitable mammographic images which can be used in different ways to aid learning. Such a large database of high resolution cases can be difficult both from a storage point of view (if stored at the point of training delivery) and also from a logistical point of view – as different breast screening and university research departments develop their own collections of images for differing purposes. However, the grid greatly facilitates such a large endeavour by allowing images both to exist, and be harvested, via different databases in different geographical locations without the need for the full dataset and user to coexist at the same physical location.

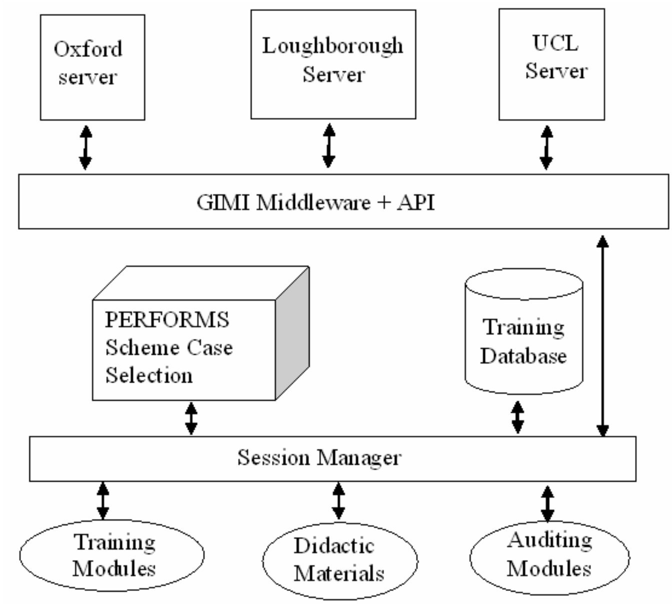

Fig. 1. Components and interoperability in the proposed Mammographic Training System

2.1 Overview: GIMI Training System

The core concept behind the current approach to training is based on the prior existence of a set of selected screening cases (each of four mammographic views; mediolateral oblique and cranio-caudal). These have been reported by one or more experienced breast screening radiologists and each case has also been annotated, such that key mammographic features have been physically identified on the images, together with some level of ontological description. Additional views and other patient imaging also exist for some cases.

The GIMI software has been developed to access the images in an intelligent manner, based on knowledge of the user training needs requirements. Images are presented on a workstation with dual high resolution monitors. The user makes decisions about each case and receives appropriate feedback. The concepts underlying the development of the tutoring system are based on the understanding of the nature of expertise in mammography [5] and on recent work in pathology [6, 7]. Figure 1 illustrates the major components in the GIMI mammographic training system and the operation and functionality of these components are described in detail as follows.

Building on the sif framework a software development platform has been constructed utilising Eclipse [8] which includes an integration of Flash and Java (figure 1). For a grid-based training system using high resolution mammographic images to be useful a key factor is that the images need to be recalled and displayed very rapidly. To do this a fast rendering DICOM image viewer was selected [9], and modifications made to it to fit into the needs of the project.

2.2 Mammographic Image Database

The initial dataset of mammographic images were sourced from a prior research project [10] which was concerned with breast screening. Some 3,200 images (800 separate cases) from this project were used here and these were dispersed across three databases situated at Loughborough, Oxford and UCL Universities. Additionally, other current screening images will be added to this dataset.

2.3 Mammographic Auditing

The images in the existing database also had associated radiological descriptions about their appearance, what features they contained, information concerning further radiological procedures (e.g. ultrasound) and pathology descriptions. Additionally, images had been carefully annotated to demarcate abnormal appearances. Consequently the image depictions were first examined for congruence to a standard and unified description so that a training system could be developed based upon this information. Not surprisingly, various cases had fuller descriptions and annotations than others. To account for this variance in the training system development then an initial auditing module was constructed which allows cases to be pulled from the database and first examined to check for full image and descriptor factors. This then allows images to be filtered from the database if they are not considered suitable for training purposes. Such auditing also facilitates the addition of new images to expand the existing database by first checking their suitability both in radiological appearance terms and in terms of the image descriptions. The auditing interface is written in Java.

2.4 GIMI Middleware

The GIMI middleware is described elsewhere [11, 12], and is designed with a service-oriented interoperability framework (sif). Sif can be considered as a conduit mechanism, which permits a number of applications to communicate with a disparate collection of geographically distributed data sources. The sif middleware is essentially a collection of web services, and provides an API (application programming interface) for application developers. The grid-enabled mammographic auditing and training system utilizes the sif middleware to build the mammographic system as an application based upon this middleware layer. The middleware interacts with a session manager which oversees and controls each actual training session.

The different software types have been integrated in this project as Java is an excellent tool for networking and communication but lacks presentation capabilities. In contrast, Flash is an excellent presentation tool but is poor in the other areas. Consequently, here we have combined these two software tools and employed XML to pass information between the Java and Flash applications.

2.5 Training Modules

For a particular trainee, cases can be selected automatically depending upon known trainee skills and factors such as an expert radiologist's judged case difficulty (for instance), to form a particular training module.

2.6 Didactic Materials

The software allows for the inclusion of any type of didactic multimedia material to be incorporated within the training modules to support training, in addition to the mammographic images themselves. Such materials can be in the form of Powerpoint, Flash presentation, video files, audio files, web links, etc..

2.7 Training Database

The working system allows a user (trainee) to register and enter personal performance data (for instance from the annual self assessment scheme or from elsewhere) so as to form an initial personal profile. As the trainee subsequently progresses through using the system then their profile is updated which can aid determination of future training needs.

3 Results

A working prototype of the training system has been developed and the interoperability of the system has been demonstrated across the three University sources. Whilst the overall concept of a grid-enabled mammographic auditing and training system has been achieved the final development and evaluation of the system is still ongoing at the present time and this is due to be completed by mid 2008. From the prototype development it is clear that there is a trade-off between the case image quality and case download time which are important factors for any acceptable training implementation.

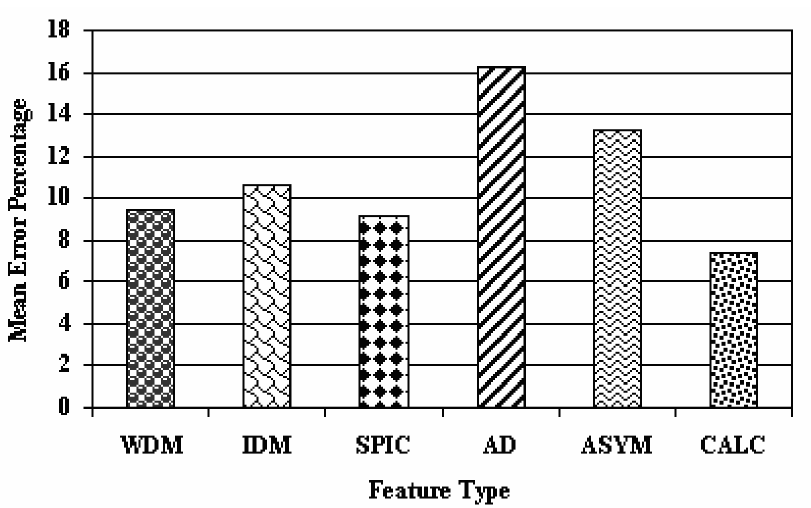

Fig. 2. Mean error percentages for PERFORMS (recent set)

To determine which training cases a particular user should be presented with there are several selection approaches, for instance using ontological information. In the current version of the system the known skills of an individual in identifying key mammographic features and/or in making a judgement about PERFORMS cases as judged against their peers' performance in examining the same cases is used. The key mammographic features which participants identify in undertaking the PERFORMS scheme map well to features in the existing GIMI mammographic database.

Data from a recent round of the PERFORMS scheme is shown in figure 2 where the mean error rate of all 560 participants is shown in identifying the key mammographic features (namely - WDM: well defined mass; IDM: ill defined mass; SPIC: spiculate mass; AD: architectural distortion; ASYM: asymmetry; and CALC: various calcification information) which were present in this particular set of difficult cases. Examples of individual participants' data are shown in the other figures. In figure 3 an individual is shown who evidences a training need for identifying two particular features, calcification and ill defined masses, whereas figure 4 shows someone who requires spiculate masses and architectural distortions additional training. Other individuals may have a need for further training in identifying a single feature, such as asymmetry (figure 5) or ill defined masses (figure 6).

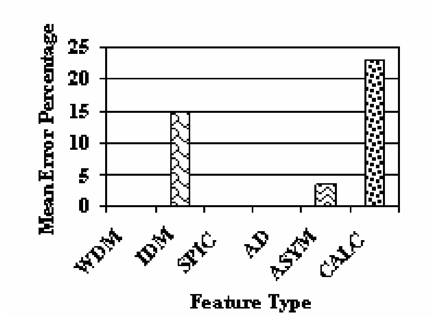

Fig. 3. Problematic features - mainly Calcification and IDM

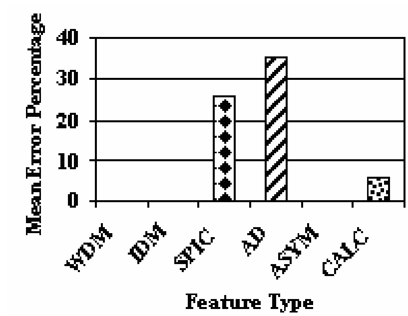

Fig. 4. Problematic features - mainly Spiculate Masses and Architectural Distortions

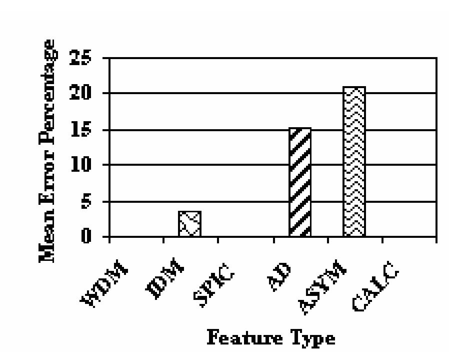

Fig. 5. Problematic Feature - Asymmetry

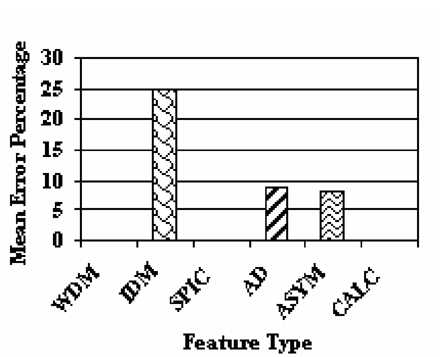

Fig. 6. Problematic Feature -IDM

4 Conclusions

The paper, which concentrates upon the system components and interoperability, demonstrates the practicality of a grid-enabled training system for mammography interpretation which is currently being finalised and trialled by mammographers. This is an important development as the UK health system moves towards data integration, data sharing, and collaboration within hospitals/clinics through grid computing. However, the research also demonstrates that network bandwidth and security are crucial issues for grid computing. Dealing with DICOM images in real time is difficult, as the image size degrades the downloading performance. In addition, the need for high resolution monitors, to display the full mammographic images, potentially limits the delivery of training utilising such high resolution images to a location where a suitable workstation is based. The tutoring system itself currently employs foreknowledge of an individual's strengths and weaknesses in reporting on known sets of difficult cases from a national self reporting scheme to inform which cases are most useful to present to an individual participant. Ongoing work is assessing the utility of this approach and is also looking to employ ontological descriptions in the future.

Acknowledgement

This project is funded by the Technology Strategy Board's Collaborative Research and Development programme, following an open competition. We acknowledge the continued support of our colleagues from Oxford University Computing Department.

References

1. Patnick, J. (ed.): NHSBSP Annual Review 2007 (NHSBSP, Sheffield) (2007)
2. Taylor-Phillips, S., Gale, A.G., Wallis, M.: Mammography Workstation Design: Reducing the Risk of Musculoskeletal Disorders? In: Manning, D., Sahiner, B. (eds.) Image Perception, Observer Performance, and Technology Assessment. Proceedings of SPIE (2008) (in press)
3. Chen, Y., Gale, A.G.: Mammographic interpretation training: how useful is handheld technology? In: Image Perception, Observer Performance, and Technology Assessment. Proceedings of SPIE (2008) (in press)
4. Scott, H.J., Gale, A.G.: Breast screening: PERFORMS identifies key mammographic training needs. British Journal of Radiology 79, S127–S133 (2006)
5. Nodine, C., Kundel, H., et al.: Nature of expertise iin searching mammograms for breast masses. Acad Radiol 3, 1000–1006 (1996)
6. Crowley, R., Medvedeva, O.: An Intelligent Tutoring System for Visual Classification Problem Solving. Artificial Intelligence in Medicine 36(1), 85–117 (2006)
7. Crowley, R.S., Legowski, E., Medvedeva, O., Tseytlin, E., Roh, E., Jukic, D.: Evaluation of an Intelligent Tutoring System in Pathology: Effects of External Representation on Performance Gains, Metacognition and Acceptance. Journal of the American Medical Informatics Association 14(2) (2007)
8. eclipse [(April 08, 2008)], `http://www.eclipse.org`

9. Laboratory of Neuro Imaging, UCLA [(June 02, 2007)], http://www.loni.ucla.edu/Software/
10. Brady, M., Gavaghan, D., Harris, S., Jirotka, M., Knox, A., Lloyd, S., Politou, E., Power, D., Simpson, A., Slaymaker, M., Williams, J.: e-DiaMoND: The Blueprint Document (November 4, 2005)
11. Simpson, A.C., Power, D.J., Slaymaker, M.A., Russell, D., Katzarova, M.: On the development of secure service-oriented architectures to support medical research. International Journal of Healthcare Information Systems and Informatics 2(2), 75–89 (2007)
12. Power, D.J., Politou, E.A., Slaymaker, M.A., Simpson, A.C.: Towards secure Grid-enabled healthcare. Softw. Pract. Exper. 35, 857–871 (2005)