

eMedI: Web-Based E-Training for Multimodal Breast Imaging

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Abstract—In this paper, a Web-based e-Training platform that is dedicated to multimodal breast imaging is presented. The assets of this platform are summarised in (i) the efficient representation of the curriculum flow that will permit efficient training; (ii) efficient tagging of multimodal content appropriate for the completion of realistic cases and (iii) ubiquitous accessibility and platform independence via a web-based approach.

Keywords—Breast imaging, e-Training, web-based learning.

I. INTRODUCTION

THE essence of a medical doctor's learning curriculum is the acquaintance with as many individual clinical cases as possible since the rate of success in diagnosis and treatment is directly proportional to the amount of this accumulated experience. This learning principle is directly applied to the field of radiology, where intensive training with medical images is required. Nowadays, the training in radiology at a European level is quite diverse both in curricula and quality due to the lack of appropriate content (tutorials and case-based learning material) as well as the lack of qualified trainers.

Furthermore, there is an increasing demand for recruiting personnel specialized in medical imaging which is proportional to the increase of produced imaging volumes. In Sweden, imaging volumes are increasing by 2% to 5% per year. The U.K. and Canada are both seeing demand for imaging growing by 5% [1]. The demand isn't likely to fall. It is obvious that there is a gap which may be largely attributed to the deficiencies of the classic training methods described in the following.

The number and complexity of the imaging modalities have increased dramatically over time. The last decades have brought about tremendous innovation in the field with magnetic resonance imaging, multi-slice computed

tomography, positron emission tomography just to name a few. The work of radiologists is becoming more complex, with the technical and IT skill demands increasing and the underpinning knowledge base also expanding. The range of tasks radiologists have to perform has increased too. These rapid developments not only require a well-prepared work force but also rapidly adapting training programs.

Additionally, training/consultation needs of radiologists working in geographically isolated regions are increased, due to limited number of cases interpreted. In this case, distance learning is a viable alternative, motivating the development of a number of web learning / training environments [2] [3] [4] [5].

In this paper, a Web-based training environment is presented, utilizing a multimodal breast imaging paradigm, aiming at facilitating accessibility and support platform independence.

Emphasis will be placed on (i) the efficient representation of the curriculum flow that will permit efficient training; (ii) the tagging of multimodal content appropriate for the completion of realistic cases; (iii) a web-based platform that permits ubiquitous accessibility and platform independence.

In this work, the focus is on breast imaging, but the results can be easily extended to other anatomical objects like brain, heart, etc.

The paper is structured as follows. In Section II, relevant existing environments will be reviewed highlighting their advantages and pitfalls. Section III is dedicated to the overall system architecture with emphasis given in the visual authoring tool. Section IV concerns the e-training environment. Concluding remarks are provided in Section V.

II. RELATED WORK

Following, recently reported e-learning systems related to radiology with particular emphasis to breast imaging, are reviewed.

In Costaridou *et al.* [6], the potential of interactive multimedia and Internet technologies is investigated with respect to the implementation of a distance learning system in medical imaging. The system is built according to a client-server architecture, based on the Internet infrastructure, composed of server nodes conceptually modelled as World Wide Web (WWW) sites. Sites are implemented by integration and customization of available components. The system evolves around network-delivered interactive multimedia courses and network-based tutoring, which

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constitute its main learning features. This potential has been demonstrated by means of an implemented system, validated with digital image processing content, specifically image enhancement. Image enhancement methods are theoretically described and applied on mammograms. Emphasis is given in the interactive presentation of the effects of algorithm parameters on image quality. The system end-user access depends on available bandwidth, so high speed access can be achieved via LAN or local ISDN connections. In this system, the content from real clinical cases was not supported by all appropriate steps for a decision making from the medical doctor. Furthermore, it focused on mammograms only, limiting breast imaging in a single modality.

In the case of the MammoEd project (<http://www.mammoed.com>) which was developed by the University of Washington, the aim was to provide interactive, comprehensive teaching cases that could be easily accessed from any computer connected to the Internet and to provide general breast imaging education resource for radiology residents, attending physicians, students, clinicians, technologists, and patients. It was developed using teaching cases from daily clinical practice organized into a computerized database. The screen-film images were scanned. The student was prompted to click on the pertinent findings or to answer questions regarding the images. Each click rendered more images and questions with discussion of the correct and incorrect answers and management issues. Links were embedded to relate teaching files and references. Although, MammoEd system deals with clinical cases from the daily clinical practice supported by corresponding images that the trainee can manipulate with minimal interactivity, it does not support multimodal content and does not permit the trainee to exploit all steps required for the diagnosis of particular cases.

In January 2004 the Bavarian statutory Health Care Administration started recertification program for quality assurance and quality improvement in mammography reading [7]. The participating physicians are required to read 50 cases randomly selected from a larger collection. The mammography films were digitized using a high-quality CCD scanner (570 dpi, 4096 shades of grey) to be viewed on an appropriate display workstation. In addition to the workstation software, a 'home edition' operating on a standard PC window was developed, allowing physicians to practice the procedure at home and get used to working with the software. Based on this 'home edition' of the software, a training CD-ROM with 35 cases was composed and distributed. Future releases of the home edition with more training cases will be in DVDs. A shortcoming of this effort is the lack of distance-based learning platform limiting access to corresponding material.

EURORAD (www.eurorad.org) is an e-learning initiative of the European Association of Radiology (EAR) that was officially launched at ECR 2001. It is the first and still the largest peer-reviewed Radiology teaching files database on the Internet, and offers free access to a wealth of medical information and imaging data, whose accuracy and quality have been validated by experienced Radiologists in Europe. However, this web-based learning environment is characterized by limited interactivity.

Aiming at providing professional education in medical imaging, Efficiency Systems Inc. launched Efficiency Learning Systems (ELS) in 2002. ELS has developed Practice Based Education™ programs that present realistic training experiences for physicians and technologists to hone and perfect their skills. "Mammography: Practice-Based Education (PBE)", created by ELS and sponsored by the University of South Florida college of Medicine, is an e-learning program dedicated to mammogram reading and provided as an interactive CD-ROM. The program's basic features are: (i) intuitive user interface (ii) a dataset of over 200 cases with proven diagnosis available for study (iii) tools for optimizing displays of images, comparing projections, marking regions of interests and constructing diagnosis report for comparison with experts. Text and reports linked throughout to definitions and reference material are also available. In a recent study [8] the PBE program was analyzed on the basis of affordance design and found to be a valuable e-learning program and an approach is a widely applicable in teaching medical image reading. Nevertheless, a shortcoming of this effort is that access is limited to corresponding material, while the interactive material is dedicated to conventional mammography lacking of multimodality training. Didactic lectures for other breast imaging modalities are available on additional CD-ROMS, however not interactive.

Wong and Hoo developed a PACS-enabled teaching file to extend clinically oriented PACS for medical education purposes [9]. They developed a multimedia file server linking the radiology departmental network and the Internet to the UCSF (University of California San Francisco) PCAS networks. Computer-aided instruction (CAI) software modules were designed, handled by separate server, to provide interactive response-driven instruction for learning breast cancer facts, screening and diagnosis.

LoRusso et al. [10] created a Mammogram teaching file, consisted of 147 cases (screening mammograms and diagnostics images such as spot compression, ultrasound and MRI). Teaching cases were constructed in a word processing doc with images inserted. Hyperlinks were available for viewing images at full size resolution in image viewer program. Feedback is provided by presentation of diagnostic images, diagnosis, discussion and references. Performance of the teaching file was assessed by means of a question survey of residents and fellows. The teaching cases mimic clinical practice and are mainly focused at developing perception skills for detecting subtle lesions. however training procedure is not fully interactive.

Roubidoux et al. developed an interactive Web-based Breast Imaging game for medical students [11]. Learning objectives were incorporated into a 16 scenarios cases with accompanying multiple choice questions. Cases were made succinct for computer display and selected radiographic images were also incorporated. A student survey was performed to evaluate technical aspects of the game and general preferences. Nevertheless, the game Web site provides images chiefly correlative purposes and not for interpretation of mammographic images (breast cancer detection and diagnosis). Specifically, the game provides mainly

instructions to students in taking clinical decisions given conclusion of a radiology report.

Additional web-based teaching files such as MyPACS.net [12] and RadPix™ (www.radpix.com) although providing detailed history and finding reports (i.e. diagnosis, discussion, references) are not fully dedicated to breast imaging and are characterized by limited interactivity. Furthermore, existing breast cases do not always provide multimodality image content.

As pointed out, the need for more comprehensive e-learning systems for training is highlighted aiming at encapsulating all available breast imaging modalities (mammography, ultrasound, MRI), simulating clinical diagnostic decision flow. It is imperative that such systems should enable ubiquitous accessibility, sharing and interoperability. The proposed e-MedI framework strives toward fulfilling the above requirements, for which a detailed description is given in the following Sections.

III. E-TRAINING FRAMEWORK

The e-MedI architecture as it is shown in Fig. 1 is based on a client-server 3-tier architecture that consists of the following core elements: (i) Learning Management System (LMS); (ii) Visual Authoring Tool; (iii) Trainee's interactive e-training environment and (iv) Keyword-guided Clinical Case search tool.

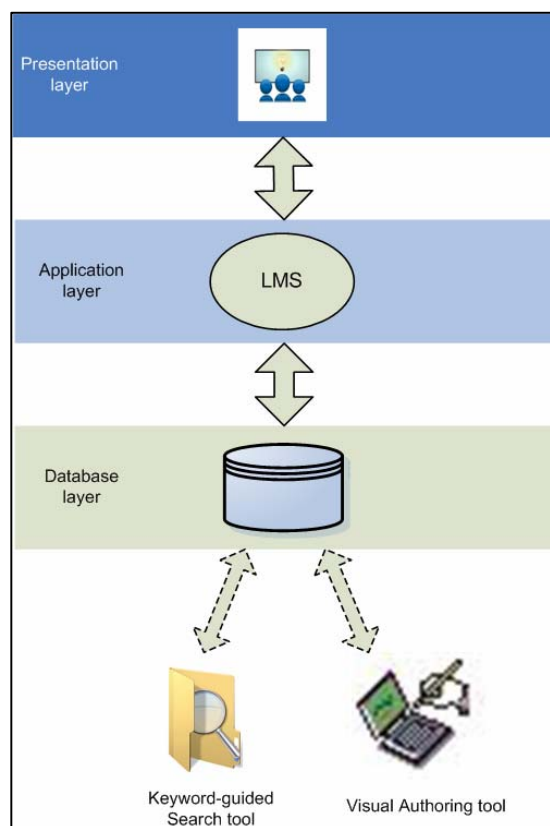


Fig. 1 e-MedI e-training platform architecture

A. LMS

The LMS is by definition a complex administrative system used to deliver electronic content in the form of lessons and to organize people who attend these lessons. In the proposed framework, we have used a proprietary LMS. Specifically, the Lotus LMS was selected for providing portability, compatibility, standard compliance and feature completeness. Lotus LMS is written in Java, which ensures, up to a certain degree, multiplatform portability. Lotus provides LMS for several popular and enterprise class platforms, thus actively supporting the generic aspect of the learning platform. Furthermore, LMS supports several databases, both free and commercially available, as its storage backend.

For a public access system such as a virtual school authentication is an essential feature. However, modern computing often requires authentication more than one time. This situation quickly becomes cumbersome encouraging people to by pass security using weak passwords, sharing accounts etc. Lotus LMS supports Single Sign On (SSO), which enables the user to be authenticated only once in order to access any service offered.

LMS scales its support from simple seminars lessons up to curriculum lessons sets. Although e-MedI does use currently only a small percentage of the full LMS feature set, this setup allows future expansion.

Finally, Lotus LMS does support SCORM (Sharable Content Object Reference Model) [13], the widely accepted standard for e-lessons, taking advantage of the multitude of SCORM tools available in the market and in the Free Software world, avoiding a potential future vendor lock-in.

B. Visual Authoring Tool

The Visual Authoring Tool is written in Java in order to maximize portability and to take advantage of future and current technologies like Java Web Start (JWS) which drive the remote execution technologies. The Authoring Tool is a custom developed software facilitating the efficient creation of Test cases for breast imaging, but it can be adapted to other types of pathology.

With the Authoring Tool, an experienced author is allowed to construct a simple test case in about a time period that ranges from 3 minutes, for a simple case, to 10 minutes for the most complex one.

In order to achieve this level of productivity and user friendliness the specifications of the Authoring Tool were crafted by an iterative process. The key features were collected in a series of feedback from a team of radiologists at a European level (Ireland, Belgium, Greece and Cyprus) and embodied into the Authoring Tool.

The Authoring Tool creates Test Cases that consist of patient's general information and a set of consecutive stages. Each Stage is a data point in patient's diagnostic time line. Each stage is associated with one or more visual content objects (i.e. 2D, 3D images and 2D+t sequences), which are the acquisition outputs of one of the available modalities (Mammography, Ultrasound, Magnetic Resonance Imaging).

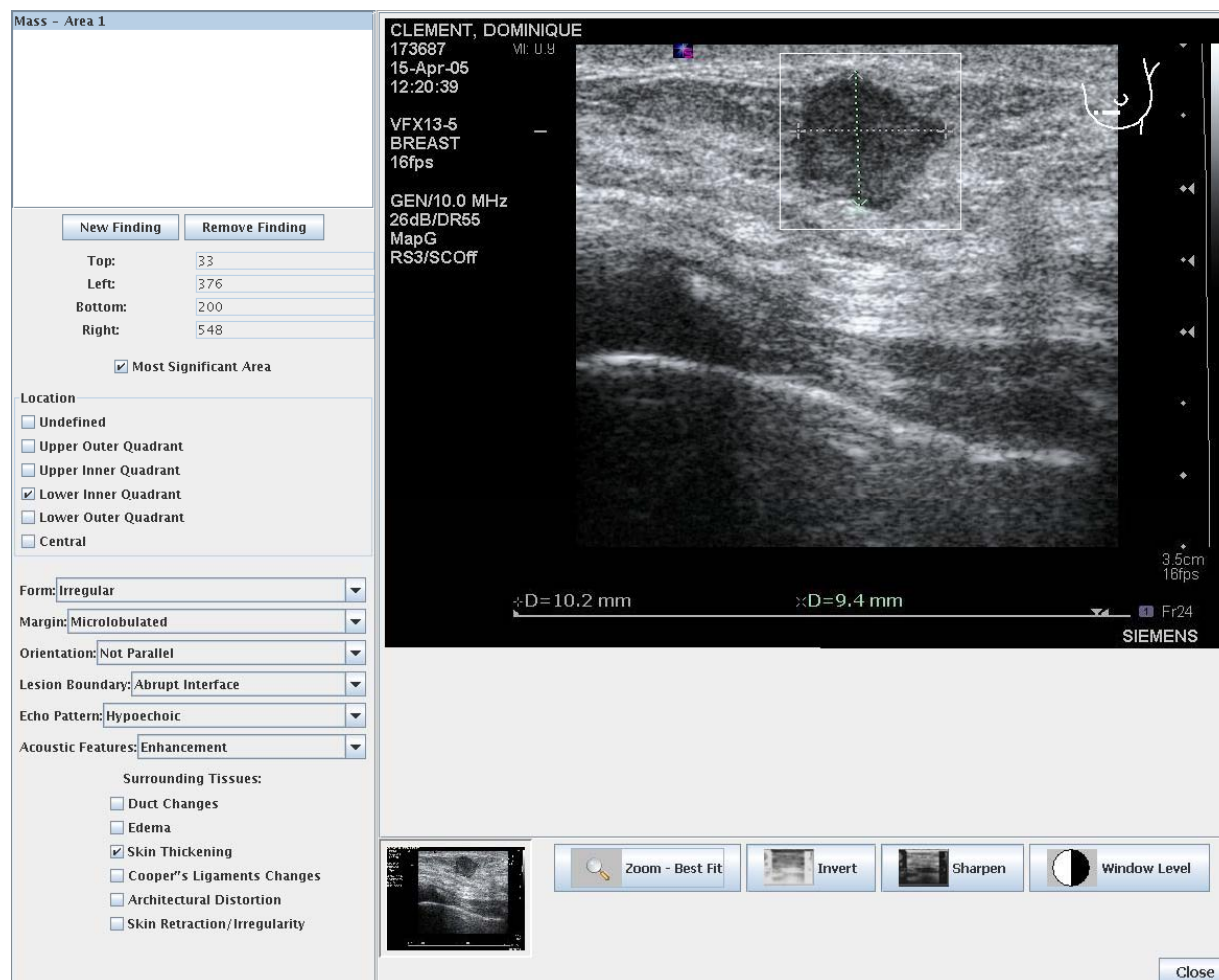


Fig. 2 An instance of the e-MedI Visual Authoring Tool environment

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At the construction of a new case, the author is initially prompted to fill a small text field providing patient's general information such as history, family history, symptoms, results from physical examination and reason for referral. Following, a Stage is created by selecting visual content objects from one modality. At each visual content object (image), the author is required to locate and describe the findings that the student is expected to identify. The description stage is supported via selection menus (combo boxes), and boolean check boxes whenever needed (Fig. 2). Additional stages are created in a similar way, if a final diagnosis can not be achieved, thus information from another modality is required. Upon finishing all the desired stages, the author is prompted to provide a final diagnosis (by means of BIRADS assessment of malignancy) and select an action concerning patient's management (e.g. biopsy, routine clinical follow-up, consult a surgeon etc.).

Finally, it is worth mentioning that the Authoring Tool gives an essential assistance to the tutors by supporting image filters such as inversion, sharpening and window level adjustments (brightness - contrast) that are routinely used by the medical doctors during an examination.

A novel feature of the e-MedI e-training platform relies upon the creation of a training flow that assimilates the real situation in a clinical environment and guides the interaction

between the trainee and the system during training. The training flow depends on the selected modality, as it is displayed in both the image properties panels and the associated findings panels. For example in a Mammogram image it is not possible to detect 'nipple retraction', so this specific option does not exist. This way the Author faces only the relevant choices, thus accelerating the process of content creation.

In the following listing, the produced XML document that depicts the training flow is discussed. Note that each XML file fully describes a clinical case.

After the XML preamble (header) that states that the encoding is Unicode in order to achieve multilinguality. For each case, a short free text with the patient's history is available along with a case follow up for future reference. The case follow up can be associated with a small image for a better overview without actually digging into the case.

The XML format described so far is like this:

```
<?xml version="1.0" encoding="UTF-8"
<case>
  <general>
    <history>
      <caseFollowUp>
        <img>
```

Since each case may have multiple stages these are described in the data section of the XML file.

```
<data>
  <stage>
    <image>
      <area>
        <associatedFindings>
        <implant>
        ...
      </area>
      <action>
      <help>
      <significance>
    </stage>
  </data>
```

closeCase represents the final diagnosis and the suggested course of action.

For example:

```
<closeCase>breastComposition="heterogeneously dense"
score="4:suspicious abnormality"
followUp="biopsy"></closeCase>
```

Each stage may have multiple images and each image may have more than one finding. In each stage it is possible for the author to specify further action (e.g. request ultrasound) and give little guidance to the trainees in the form of popup windows (<help> tag)

Each area of the image has only one finding. The Image node has the following tags:

```
<file>: image filename
<label>: window title, the title of the window displayed during the training
<display>: left, right or both breasts
<modality>: mammo, ultrasound or MRI.
```

In the area tag the ROI coordinates are stored along with the finding's type e.g. calcification. The associated finding tag holds the options that are displayed in the above figures and they are modality specific.

If the interesting spots in an image are not immediately visible the Authoring Tool provides the means for window level adjustment (brightness - contrast) which fits naturally into the doctor's work cycle.

Finally the program gives the opportunity to classify a finding as implant in order to avoid further evaluation.

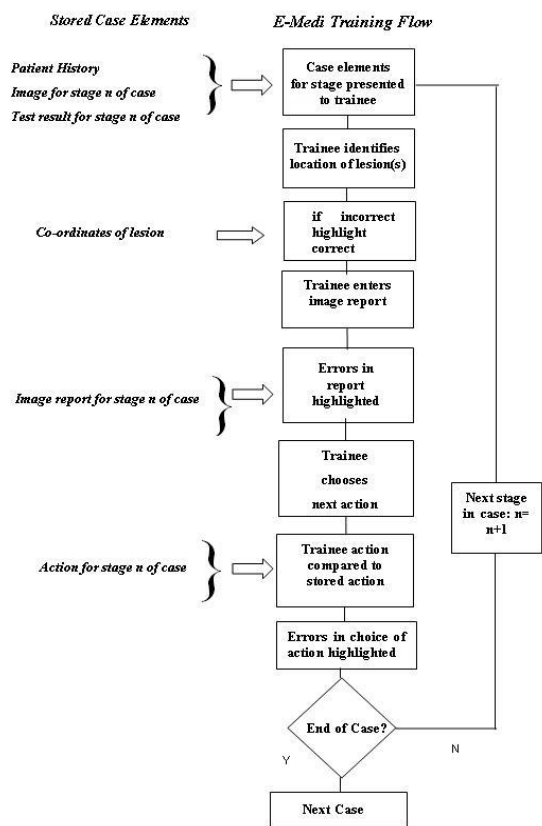


Fig. 3 Core interaction between the trainee and e-MedI for a single case

IV. INTERACTIVE E-TRAINING ENVIRONMENT

The presentation tier is the layer of user interaction. Its focus is on efficient user interface (UI) design and accessibility throughout the training process. The UI tier can reside on the user's desktop, on an Intranet, or on the Internet. Furthermore the e-training environment is multilingual with translations in english, french, and greek already available.

The proposed core aspects of e-MedI as experienced by the trainee during interaction are presented in Figure 3. This flowchart shows the core interaction between the trainee and e-MedI for a single case. Outside of this core, additional functionality will exist to manage case selection, presentation and entry of cases into e-MedI. For example, additional functionality could be envisaged to filter cases into categories (eg. 'easy' to 'difficult'), alter the appearance of the user interface, or provide the trainee with scores and tutorials.

Inside the core, data are revealed gradually to the trainee, following a sequence of *stages*. For example, at the first stage, patient's general information (history etc.), results from physical examination and corresponding images are available. The trainee is initially prompted to identify location of suspect lesions on each image (by clicking). The chosen locations will be crosschecked with the stored lesion coordinates for that image.

Following, the trainee enters a report for the current image using a report data entry table, which displays a range of standard image features such as “mass”, “mass margins”, “mass density” etc. Each feature reflects standard descriptors, associated with a checkbox in the report entry table. Errors between the report entered by the trainee and the stored report can be highlighted. Upon selection of correct report, trainee must then select the next action from a predefined list, using an on-screen push button, dropdown list or similar. Next possible action can either be a following stage (e.g. “carry out ultrasound” and “carry out spot compression mammogram”) or closing of the case by providing a final diagnosis (e.g. “score BiRads”).

An important feature is that images from different modalities may be available at the same screen providing the trainee the opportunity to diagnose simulating the real diagnosis process. This can be shown via a snapshot of the interactive e-training environment at Figs. 5, 6.

A. Keyword-Based Clinical Case Search Tool

The e-MedI database holds all available visual content along with their corresponding descriptors. The keyword-based clinical case search tool allows searching through keywords with the aim to assist the user in finding visual content instances eg. 2D images that have specific features in order to further improve training in a particular case diagnosis. For example if the user has in a mammogram that may have a ‘ruptured implant’ and wants to verify the diagnosis, he/she can use this feature as keyword to retrieve all relevant visual content.

Searching is realised by querying with different granularity. An example is shown at Fig. 4. First, the user of the system selects what type of image wants to search eg. Mammogram, Ultrasound or MRI. After that, based on the selected modality, the user selects among all the modality-specific descriptors those that are needed for the particular image the user searches for. Some descriptors are further refined by clicking on the button refine next to it.

V. CONCLUSION

The proposed platform for e-training on breast imaging draws its importance from the underlying principle that a fruitful training process has to assimilate and subsequently follow a training flow which corresponds to a valid step-by-step process followed in a real clinical routine setting. This principle is realised via the e-MedI through mainly an authoring tool that supports the creation of the realistic flow as well as an interactive environment that is both user friendly and enables the acquaintance of the trainee with the training flow process. e-MedI can support an ubiquitous trainee due to its web-based design providing the students useable skills that they can directly apply in the real world. In our immediate future plans, we will apply to corresponding authorities all over Europe that support Continuous Medical Education certificates to consider e-MedI as the means of accreditation on breast imaging.

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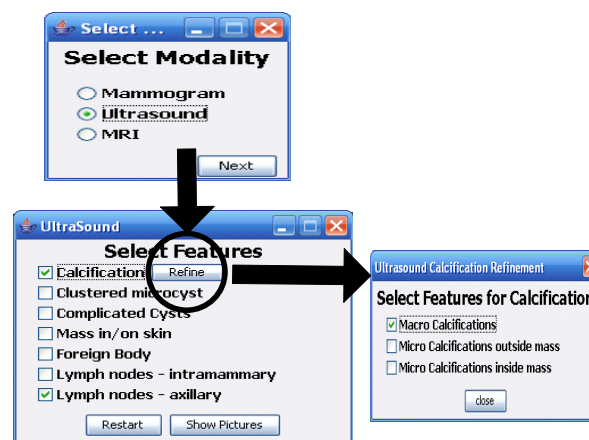


Fig. 4 Example of a refined query

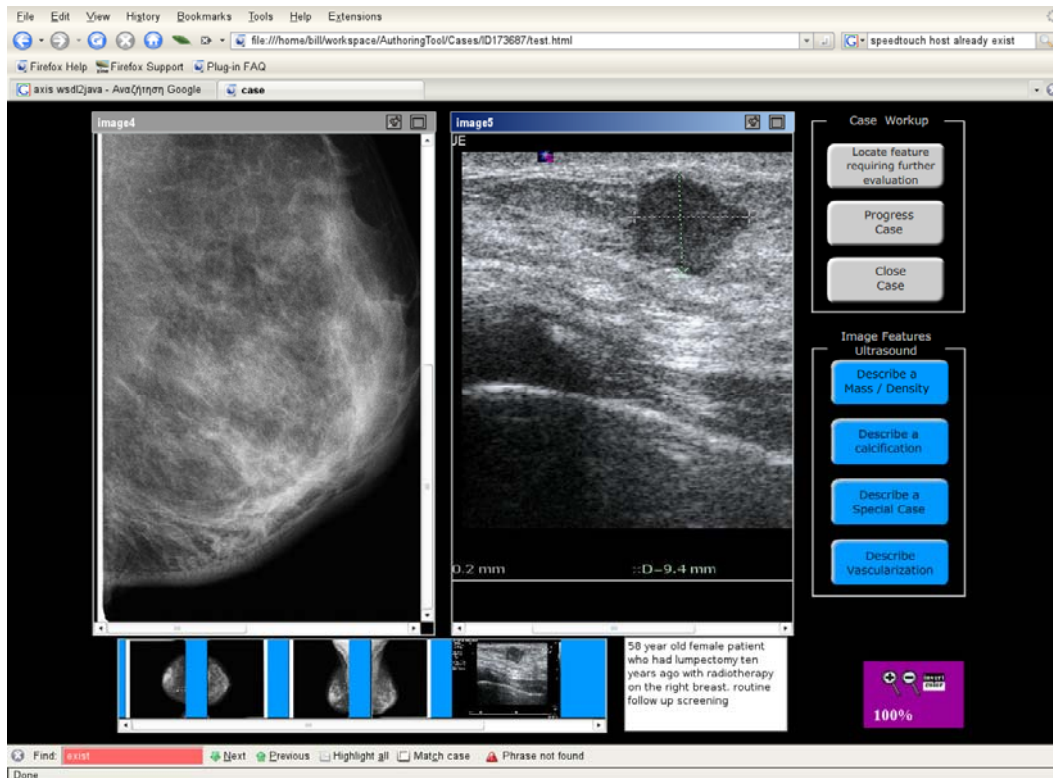


Fig. 5 A snapshot of the interactive e-training environment

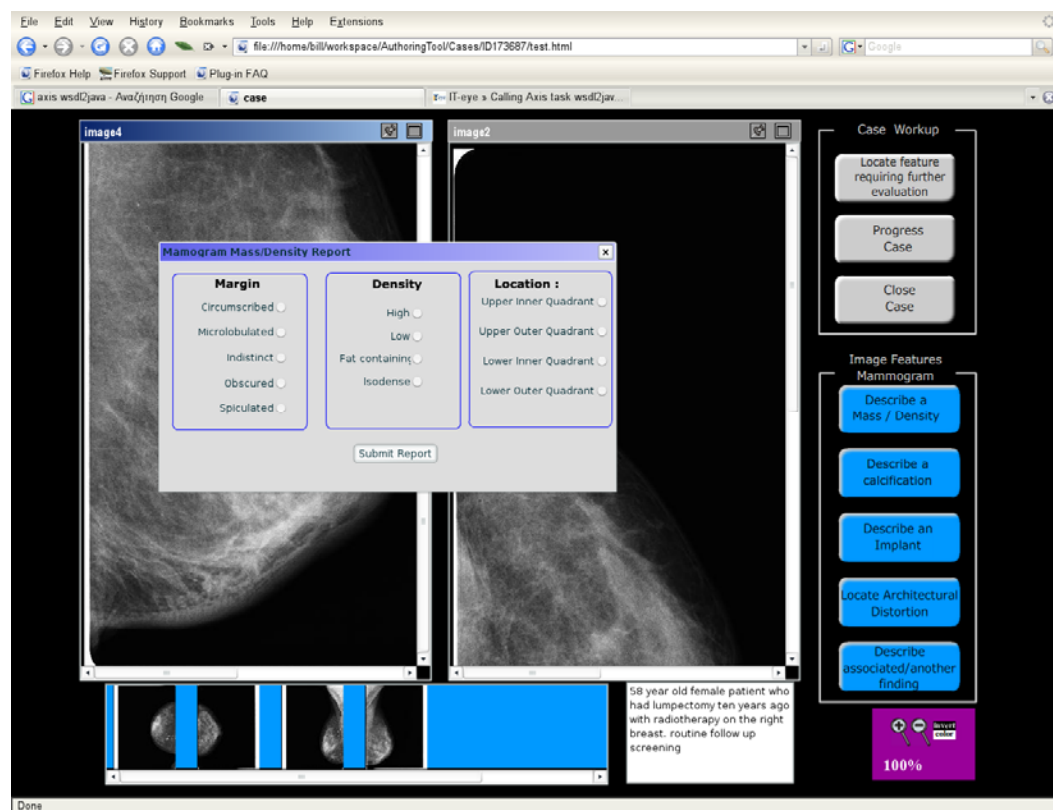


Fig. 6 A snapshot of the interactive e-training environment – Mammogram / mass density report