A Web Simulation of Medical Image Reconstruction and Processing as an Educational Tool

## Abstract

Web educational resources integrating interactive simulation tools provide students with an in-depth understanding of the medical imaging process. The aim of this work was the development of a purely Web-based, open access, interactive application, as an ancillary learning tool in graduate and postgraduate medical imaging education, including a systematic evaluation of learning effectiveness. The pedagogic content of the educational Web portal was designed to cover the basic concepts of medical imaging reconstruction and processing, through the use of active learning and motivation, including learning simulations that closely resemble actual tomographic imaging systems. The user can implement image reconstruction and processing algorithms under a single user interface and manipulate various factors to understand the impact on image appearance. A questionnaire for pre- and post-training self-assessment was developed and integrated in the online application. The developed Web-based educational application introduces the trainee in the basic concepts of imaging through textual and graphical information and proceeds with a learning-by-doing approach. Trainees are encouraged to participate in a pre- and post-training questionnaire to assess their knowledge gain. An initial feedback from a group of graduate medical students showed that the developed course was considered as effective and well structured. An e-learning application on medical imaging integrating interactive simulation tools was developed and assessed in our institution.

**Keywords:**Web-based education, Simulation, Reconstruction, FBP, Iterative algorithm, Medical imaging, Image processing, Filter, CT, SPECT

## Background

Medical imaging has evolved into a key component of both clinical and research laboratories. Clinical applications include diagnosis, treatment planning, and surgical guidance. Continued imaging innovation has augmented the versatility of medical image reconstruction, processing and storage alternatives that need to be swiftly assimilated by medical practitioners and medical auxiliaries. Raising the level of future professionals training to keep up with the rapid developments in the field thus becomes more and more important, as does the need for a comprehensive medical imaging education program.

The majority of studies on learning outcomes suggest that Web-based educational interventions are effective in enhancing knowledge, attitudinal, and, to a lesser extent, skill domains. Web content adds graphics, sound, and video, so as to give teachers and trainees multiple paths for teaching and understanding. Information can be presented interactively, and trainees can choose the time, place, and pace of learning. Hyper-textbooks are a source of online education that provides additional multimedia elements, as opposed to traditional textbooks. However, hyper-textbooks do not offer interactive computational modules that provide users with the imaging algorithms used in the various medical imaging modalities. The literature offers an increased number of articles for Web-based medical education, but only a few of them are medical-imaging-oriented, while less provide the combination of text explanations, animations, and simulations. These references are of little help to most persons who lack the mathematical perception of physicists and engineers.

In an effort to address these aspects, we developed an open access purely Web-based, interactive educational application with simulation and self-assessment features, for training medical students, physicists, and engineers studying medical physics and radiology residents, on the basic concepts of medical image reconstruction and processing. Effort was also made to include in the developed educational application hands-on experimentation to the trainees in order to enhance their understanding of how medical images are formed and processed. A multiple choice questionnaire regarding the content material of the course has been incorporated in the Web-based platform, so that the user can self-evaluate his or her knowledge on the referred topics.

## Materials and Methods

### Design Considerations

The educational content of the online course focuses on the reconstruction and processing of medical images rather than on case-based medical instruction. The educational platform has been designed to include the following features: (1) the basic concepts of the Digital Imaging and Communications in Medicine (DICOM) protocol for storing and transferring medical images, (2) the principles of acquiring projections forming the sinogram of an imaged object, (3) the principles of reconstructing tomographic images from their projections using either the filtered back projection (FBP) or iterative reconstruction (IR) methods, and (4) image processing using (a) the information from the corresponding intensity histogram and (b) a number of filters applied in the spatial or frequency domains. A number of options were provided for assisting users in the understanding of the parameters that affect medical image quality, quantified using the modulation transfer function (MTF).

The structure of the course has been designed to present the basic topics of medical imaging in a short and intuitive way before proceeding to interactive image reconstruction and image processing. The design of the application is characterized by the degree of flexibility necessary to present the user with the option to navigate through the above-mentioned three pedagogic sessions as well as in between them, thus allowing learners to skip information they already know and move on to subjects they are less familiar with.

The referenced methods for acquiring medical images are tomographic systems of Radiology and Nuclear Medicine. While a number of phantom images (test objects) are included in the simulation tool to facilitate understanding of the studied topics, the users are also able to upload their images in DICOM format.

Password-protected access was chosen mainly to permit the creation of user profiles for the tracking of self-improvement. Emphasis has been given to the simplicity, time efficiency, and privacy protection of the account creation procedure.

### Developing the Web-Based Educational Platform

Effective online learning requires the developer to carefully construct a program that integrates principles of active learning, motivation, and evaluation with creative Web design . The interactive Web portal has been developed to host the educational application, based on the system architecture of a server and a client layer (Fig. [1](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4305051/figure/Fig1/)) and consists of 52 Web pages. The server receives requests through the client Web browser over the internet using the Internet Information Services (IIS). The Web server is responsible for handling all the requests that are coming from clients. When a request comes from client to server, IIS takes that request, processes it, and sends a response back to the client.

If the request includes graphics processing, the IIS calls one of the 83 customized computational modules developed in house using MATLAB® to handle it. Similar work has been also performed by Wu et al. and Dikshit et al., who developed an intuitive interactive curriculum for Miami University, USA, using MATLAB Web Server software. As of MATLAB Release 2006b, MATLAB Web Server was discontinued and Mathworks no longer supports the Web server. Our interactive platform is based on server-side .NET components created by MATLAB Deployment Tool and incorporated in the developed .NET Web application. The framework .NET stands for the software package that provides language and service interoperability. Two different programming languages were used to manage the webpage interactivity. C# code handles server-side functions, while JavaScript code performs client-side functions. Client data, like the user profile, is stored in a linked server database using structured query language (SQL). All educational graphics and animations were designed or formatted by MATLAB Image Processing Toolbox and along with several interactive tools of image processing and reconstruction are accessible to everyone. These technologies were appropriately combined to achieve real-time interactivity and simulation.

### Self-Evaluation

Based on the educational content of the online course, a 22-question multiple choice quiz has been integrated in the Web platform of the application. The questions of the multiple choice quiz have been strategically chosen to evaluate in-depth understanding of the course content (Fig. [2](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4305051/figure/Fig2/)). The learners are advised to take the same multiple choice questionnaire pre- and post-training (maximum allowed time is 22 min or 1 min per question on average). The number of times that the learner can answer the questionnaire is not constrained by the educational tool. The score of the learner each time he or she takes the questionnaire is stored in the database and can be used for self-assessment of the gained knowledge.