Collaborative Development of Internet-Accessible, Interactive, Medical Imaging Teaching Courseware and Application to Undergraduate Curricula

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Abstract

Medical imaging education is interdisciplinary in many engineering programs, most typically Biomedical Engineering. Medical imaging techniques involve physics principles, mathematical derivations, and engineering implementations for image generation, reconstruction, and instrumentation. Finding an efficient way for instructors to deliver medical imaging knowledge and establishing an effective learning environment for students, especially at institutions without associated medical schools or hospitals, have long been goals for medical imaging educators. We proposed to develop an Internet accessible, interactive medical imaging teaching system serving the courseware for medical imaging classes. Three institutions in South Florida have participated in the development and application of this system. Our effort has been focused on the creation of animations for physics/chemistry principles and simulations for engineering implementations. The animations or simulations are interfaced with user-adjustable parameters or settings so that the physics/chemistry/engineering principles can be dynamically and interactively demonstrated. A "live" medical imaging device or component can be presented without accessing the real equipment. We have opened this teaching system in different size classes on all or selected imaging modalities during the last few years. More than 200 students in three institutions have accessed the Website. The assessment result (pre/post) shows increased learning gains, especially significant in concept understanding.

Introduction

Medical imaging education is popular in undergraduate engineering curricula. Medical imaging related courses, such as Physics of Medical Imaging, Medical Imaging Signals and Systems, Image Reconstruction Principles, are usually offered by electrical engineering, computer engineering, and particularly biomedical engineering programs. Based on the Whitaker Foundation's BME program database[23], there are 122 universities or colleges that have BME programs in the nation. We surveyed these universities or colleges and found that 80 of them offer graduate level medical imaging courses, and 68 offer undergraduate level medical imaging courses. We must acknowledge that the survey was based on the Internet available and accessible information in 2010 and it may not be the most accurate or updated. However, it clearly presents a significant demanding signal for medical imaging education required by undergraduate engineering curricula. Medical imaging, combining physics, mathematics, electrical and computer engineering, provides students with a broad view of an integration of different technologies applied to biology and medicine. Different imaging modalities involve various physics principles, diverse mathematic derivations for image generation, recognition and reconstruction, special system configurations and specific applications. The tremendous amount of information and rapid change in the medical imaging field require teaching material to be more flexible to fit into the available class hours. Obstacles to medical imaging education include 1) class hours required because of the interdisciplinary features, 2) sophisticated mathematical modeling required for many imaging systems, 3) inaccessibility or local unavailability of the imaging devices. Finding an efficient way for instructors to deliver medical imaging knowledge and establishing an effective learning environment for students, especially at institutions without associated medical schools or hospitals, have long been goals for medical imaging educators.

Comprehensive discussion for undergraduate medical imaging education has been published[25]. Efficient teaching for faculty and effective learning for students are crucial to the success of medical imaging education[16,21]. Internet/web-based education (a major subcomponent of the broader term "e-learning") is one of the tools with which education is popularly delivered[6,7,13,28,29]. Education through the Internet makes it possible for more individuals than ever to access knowledge and to learn in new and different ways. Efforts have been made in different aspects, such as image reconstruction techniques varying from the very theoretical[8,20,30], to the math-intensive[9,27], to algorithm efficiency and to image quality improvement[1,24]. However, limited efforts actually describe, step-by-step, the process of generation of image data, which is the fundamental educational component of medical imaging. Hyper-textbooks are a source of "dynamic" online education that provides additional multimedia elements, as opposed to "text-picture" only textbooks. Several hyper-books[4,15] are popularly used for medical imaging courses. Most hyper-textbooks provide a "one-way" active teaching model without interactivity. Interactivity among instructor, teaching material and students is a proven effective way to improve teaching efficiency[2,3,14]. Interactive learning environments can provide multiple means of representation and expression for the learner through text and graphic modes, animated simulations and other combinations of the media. Interactive education aids in increasing the student's comprehension, motivation level and perception of learning[5]. Interactive modules allow students to tailor presentations to suit their own exact needs with sound, animation and video capturing the viewer's attention and conveying explanations more effectively[22]. On the other hand, the Internet's interactive feature is usually utilized well but its advantage to learning evaluation is often neglected. For example, the Internet provides the teaching-learning process an efficient and automatic means to receive un-biased feedback by designed assessment functions[19,26]. A dynamic tracking system embedded in the Internet accessible interactivity teaching software is highly desirable to use the Internet's un-biased and online feedback feature to influence evaluation.

Educational Hypothesis and Project Objective

The motivation to start the project was to match student's learning style[10], "I hear and I forget, I see and I remember, I do and I understand." Based on the following teaching/learning pedagogy, "A picture is worth/better than a thousand words", i.e., using pictorial description would be superior to the text-only description. We extended the idea, "A moving picture is better than a static picture," (by using Adobe Flash Player or Media Player). Furthermore, we added, "An interactive moving picture is better than a simple moving picture," (by adding interactivities). The hypothesis for this project is that interactive animation or simulation increases teaching efficiency and promotes effective leanring. Our objective is to design and implement an online user-interactive teaching/learning system, featuring animation and simultion for physical principles, mathematical derivations and engineering implementations, so as to fulfill the medical imaging education tasks optimally.

Design

In order to develop a system that be shared by as many courses as possible, we construct the system into course, modality, module and component levels. Figure 1 below shows the hierarchy of the medical imaging teaching/learning system.

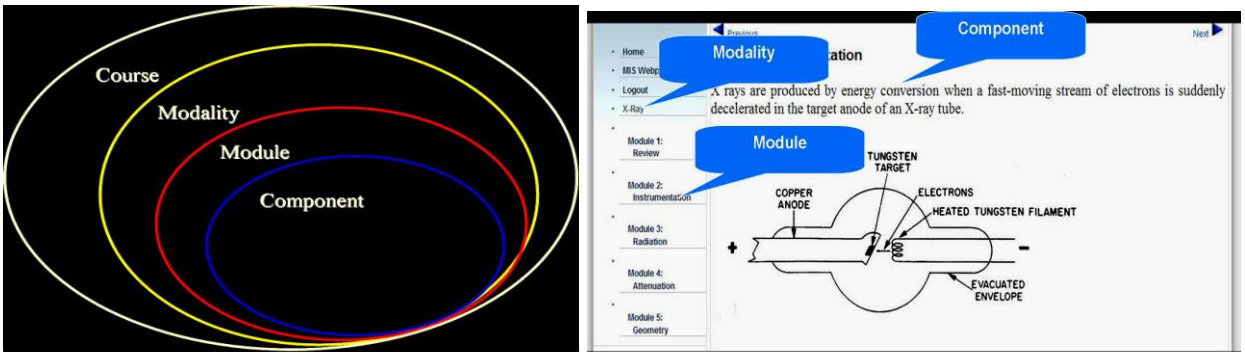

Fig. 1: Medical imaging knowledge is built upon different scaled elements that are connected to each other. Left panel: Concept of nested medical iamging teaching/learning system. Right panel: Desugn example of the X-ray instrumentaiton within the X-ray imaging modality.

To serve as many courses as possible, we organized the Medical Imaging Teaching System (MITS), based on Imaging Modalities, which are defined by imaging techniques (X-ray, CT, MRI, Nuclear Medicine Imaging (NMI), Ultrasound) and associated with Image Processing (IP) utilities. Within each imaging modality, we created several Modules. Each module corresponds to a lecture topic. Each module includes five supporting Components (*background review, text-figure description-illustration, animation, simulation, and application examples*). This design helps maximally utilize the supporting components and also provide the path for a step-by-step learning. In order to assess student's learning gain and obtain feedback from student learning, we also designed an evaluation database that records student's engagement time, pre/post quiz/test results, through the Dynamic Assessment Tracking System (DATS). The figure below shows the MITS/DATS structure.

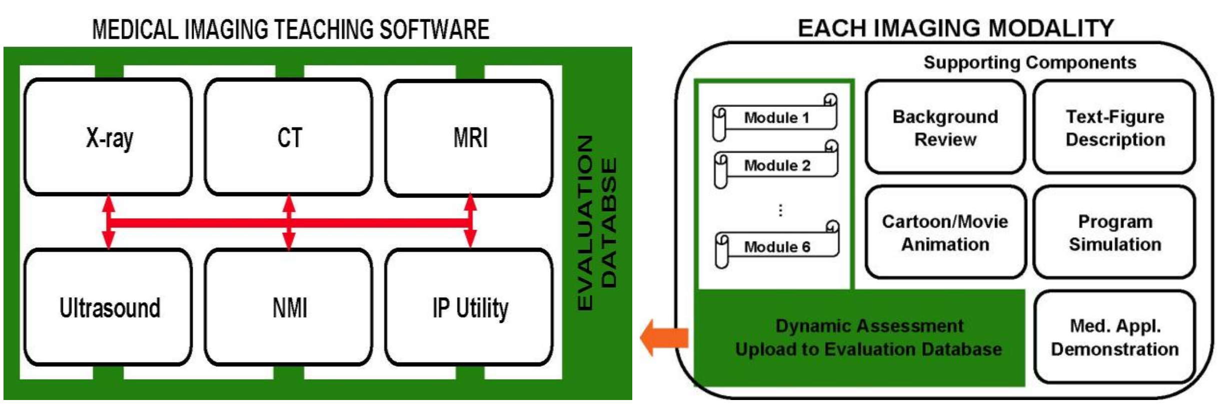

Fig. 2: Medical imaging teaching software is organized by imaging modalities and associated with an evaluation database. Each module is delivered by five supporting components to ensure the information transferred in all aspects.

Implementation

After the structure of the system was determined, we built the system by completing the supporting components. We only briefly describe the implementation for the animation component. Description for other components can be found in previous publications[18,31]. *Animation and Simulation* components are the focus in the MITS system. Cartoon/movie animation provides students an interactive environment to visualize a "dynamic" physical process or a "live" instrument (by Adobe Flash Player, Windows Media Player, or even MS Power Point Presentation). We give two examples as follows.

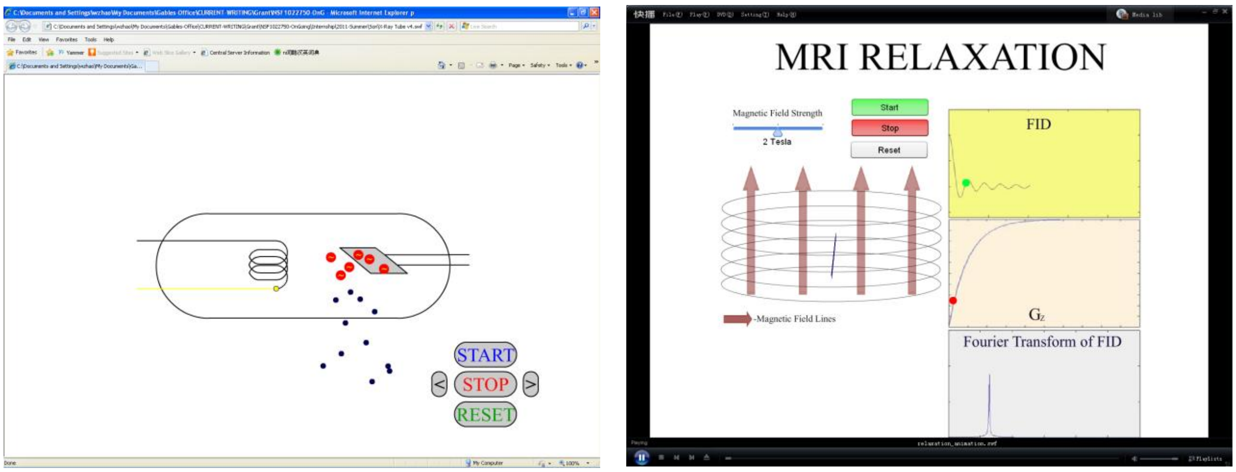

Fig. 3: Left panel illustrates a model of an X-ray tube. When the START button is clicked, a current (yellow) will run through the coil, free electrons on the surface of the coil will fly to the plate. The collision will produce heat (red) and X-ray (blue). Step-by-step interaction is available by clicking > or < button. Right panel illustrates an MRI instrument model. The animation shows how the cellular-level magnetic element in the human body (the small bar inside the coil) reacts under external magnetic field. When the intensity of the external magnetic field (scroll bar) is interactively justified, the corresponding reaction of the cellular-level magnetic element in the human body changes accordingly. How the electrical signal induced by the changes is also demonstrated.

In order to assess the teaching/learning efficacy, we use a Dynamic Assessment Tracking System (DATS), a username/password required system, to obtain feedback from the MITS system. An instructor can enroll his/her students into the system. Students can go through each module at a self-paced fashion. Pre-post quiz-test questions have been included in the system and are pulled out by student randomly. The DATS system is illustrated as following.

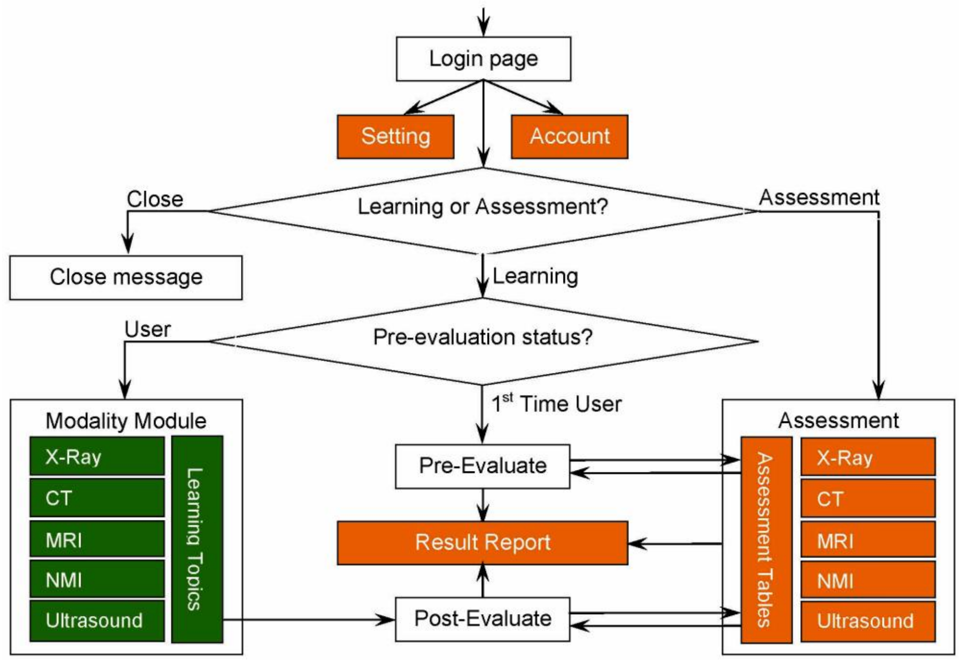

Fig. 4: The dynamic assessment tracking system (DATS) enables Independent Administrator Control (instructor). The system allows new instructors to join the system from the same or different institutions as site administrators. This system is username/password protected and Internet accessible. The assessment of student performance can be acquired by instructor through the online database.

The system was exposed to classes in three participating institutions for medical imaging teaching. Class sizes were various every semester (Florida Atlantic University:12, Florida International University:40, University of Miami:50). The MITS system was used as a hybrid protocol, i.e., students were assigned to read and conduct the MITS materials following each lecture. Student's performance was not counted for their final grade (this protocol was approved by each IRB office). The MITS/DATS system locates http://mis.eng.miami.edu.

Results

Class Performance: We tested two classes' performances on learning all modules associated with X-ray and CT modalities. The tests were given to one class without MITS and the other with MITS through a hybrid teaching model. Students' academic, and class performance records (mean±SD) of without (n=23, top row) and with (n=21, bottom row) are listed in table below.

Table 1: Performance on Learning X-ray and CT

Classes	GPA	All Prob.	Concept Prob.	Projects
N=23	3.42±0.34	82±9%	76±5%	82±5%
N=21	^{*1}3.46±0.44	^{*2}89±8%	^{*3}91±6%	^{*3}90±6%

Statistical comparison (ANOVA, Single factor) of students' cumulative GPA shows no difference between two classes ($*^1 p \leq 0.7$), indicating similar background of students in two classes. This comparison was conducted to confirm that if any improvement occurred from the application of MITS was NOT caused by students' background difference. Statistical comparison of students' correct percent rate for all questions ("All Prob.") shows no significant difference; however, the low p-value (*[2]$p \leq 0.1$) implies a "trend" of increased understanding to all questions (conceptual and computational). Students' understanding improved most in conceptual questions[17] ("Concept Prob.") and in their projects. Both statistical comparisons show significant differences (both *[3]$p \leq 0.05$) between two classes.

Learning Gain: We conducted a test to examine student's understanding on imaging principles through the MITS directly. This was done by giving students concept questions before they read the corresponding module (independent of lecture) and immediately after they read the module. We did a preliminary calculation of students' learning gain by the normalized equation[11,12], LG= (post-pre)/(100-pre). We found that the average students learning gain (n=37 for both years) on 17 basic medical imaging concepts was 0.36±0.28.

Table 2: Student learning gain measured from two classes from 2009 and 2011.

	2011 (n = 22)					2009 (n = 15)				
	Pre-test		Post-test		Gain	Pre-test		Post-test		Gain
Questions	Correct	Wrong	Correct	Wrong		Correct	Wrong	Correct	Wrong	
1	22	0	22	0	**0**	14	1	13	2	**-1**
2	15	7	20	2	**5**	11	4	14	1	**3**
3	17	5	19	3	**2**	9	6	15	0	**6**
4	20	2	21	1	**1**	14	1	14	1	**0**
5	15	7	15	7	**0**	7	8	12	3	**5**
6	20	2	20	2	**0**	12	3	15	0	**3**
7	11	11	14	8	**3**	7	8	11	4	**4**
8	10	12	14	8	**4**	7	8	11	4	**4**
9	9	13	13	9	**0**	7	8	14	1	**7**
10	8	14	12	10	**2**	4	11	11	4	**7**
11	7	15	13	9	**6**	8	7	8	7	**0**
12	19	3	22	0	**3**	13	2	11	4	**-2**
13	9	13	11	11	**2**	6	9	12	3	**6**
14	6	16	16	6	**10**	3	12	12	3	**9**
15	20	2	22	0	**2**	12	3	15	0	**3**
16	8	14	21	1	**13**	5	10	15	0	**10**
17	14	8	15	7	**1**	5	10	8	7	**3**

Subjective Perception and Student Engagement: During the development of the MITS/DATS system, we gave students surveys that collected their subjective perceptions. The feedback surprised us by the disparities between the junior class and the senior class. We also surveyed the same students' engagement with the MITS/DATS system. The engagement was measured by the time used for the first time to sign on the system, each time used with the system, and the time used to study animations and simulations. We noticed a similar disparity between two classes. Various reasons might cause the disparities. However, it is noticeable that the engagement is proportional to the subjective perception. The more use of the system, the more positive feedback is collected from the users.

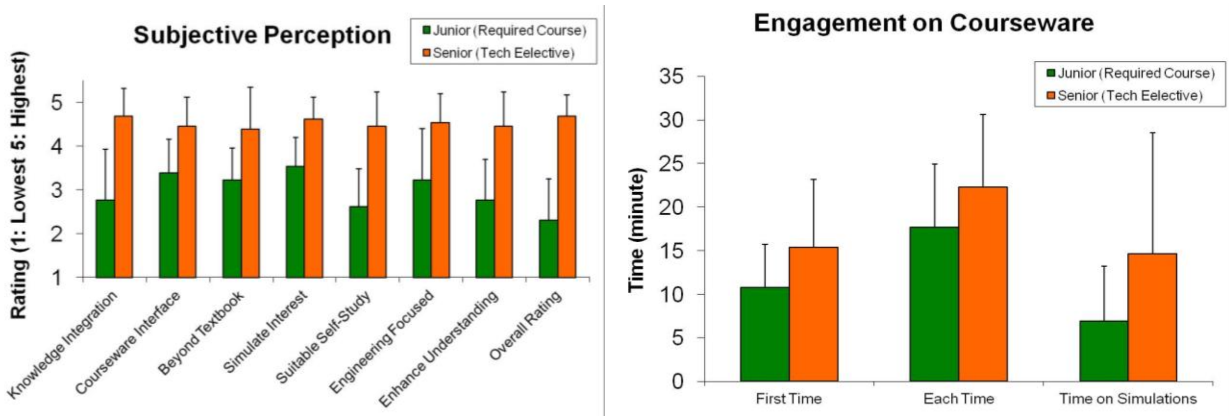

Fig. 5: Students' subjective perceptions to the application of MITS/DATS show apparent disparities from different level of classes. Students' engagements with the MITS/DATS system also show strong disparities from different level of classes.

Conclusion

Based on the outcomes and the evaluations of different assessments, we conclude that the developed MITS/DATS system is suitable and applicable for medical imaging curricula to undergraduates. We plan to scale up the development and application (large number of student enrollment) through the efforts by other participating institutions to produce a professional medical imaging teaching product that can be adopted by interested academic institutions.

Acknowledgement

This study has been supported by NSF grants since 2002, from the phase of "Proof of Concept" (NSF DUE0123759) to the phase of "Build a Prototype" (NSF DUE0639752), and to the current phase "Expansion Development" (NSF DUE1022750).

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