Biomedical Imaging course: Challenges and Solution

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Abstract

The primary role for medical imaging has been diagnostic, but there is increasing use of medical imaging modalities including endoscopy, x-ray fluoroscopy and computed tomography (CT), ultrasound, and magnetic resonance imaging (MRI), for interventional diagnostic, therapeutic and guided surgery.

Rapidly evolving changes in the healthcare coupled with the advances in imaging has necessitated rapid change in biomedical engineering education. These rapid changes in biomedical engineering reflected rapid expansion of biomedical imaging. It is multidisciplinary field, which involves learning physics principles, mathematical derivations and engineering implementation, including instrumental design, data acquisition strategies, image reconstruction and generation techniques, and the clinical applications and technologies such as X-ray, Magnetic Resonance Imaging, Computed Tomography, Ultrasound, Fluoroscopy, etc.

The filed of biomedical imaging provides a broad view to students the integration and implementation of different science, engineering and technology in medicine. There are many obstacles for teaching biomedical imaging courses, especially for undergraduate studies particularly in institutions without direct association with a medical school or hospital.

At Wentworth Institute of Technology new Medical Imaging course with theory and lab components has been developed and results have been analyzed. This paper features the implementation of internet accessible, medical imaging teaching software and dynamic assessment tracking system developed for teaching five commonly used imaging modalities.

INTRODUCTION

Biomedical engineering (BME) is as an interdisciplinary engineering field. It integrates sciences like physics, math, chemistry, computer science, biology and engineering with the medicine. The data from the Whitaker Foundation's BME program database [10,20], shows there are more than 120 universities and colleges with BME programs in the USA and BME undergraduate enrollment has become one of the most rapidly growing engineering majors. This is clear indication of how big the demand is/would be for the medical imaging education. As shown in figure 1 BME undergraduate enrollment has tripled during the last decade.

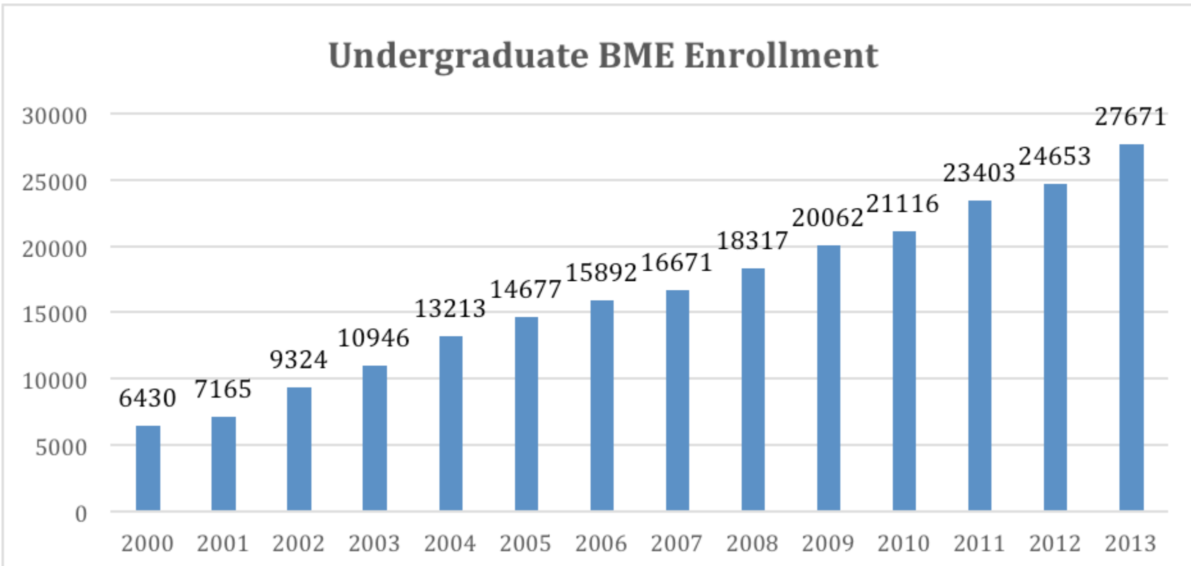

Figure 1, Undergraduate students enrolment 2000-2013.

There are various curricular settings that are designed for different levels of student's learning objective in medical imaging but X-ray, Computed Tomography, Magnetic Resonance Imaging, Nuclear Medicine Imaging and Ultrasound are commonly used clinical imaging modalities which are often taught through a series of courses, with different emphasize on physics, signals, reconstruction and hardware. As can be seen with increasing number of students enrollment, the medical imaging education would be popular in undergraduate engineering curricula with different related emphasizes and approaches, such as Physics of Medical Imaging, Medical Imaging Signals and Systems, Image Reconstruction Principles [11]. The medical imaging shows appreciation of basics science and how integrate multidisciplinary studies in one problem and it opens a wide career opportunity for undergraduate or graduate students in medical instrumentation, equipment, signal processing, imaging fields and etc..

Information regarding medical imaging field changes rapidly and that requires flexible teaching and learning time and style that would fit the curriculum outcomes, objectives and time [5,6,8]. This would cause obstacles like duration of class and lab time, knowledge of basic science and math, programing skills and most importantly having association with medical school or hospital and access to the imaging devices [19]. Association with the hospital or medical school is the most challenging and caused Biomedical imaging educators to look for alternative ways to instruct the modalities. In the recent years e-learning (virtual labs, web-based education) became an efficient way to teach and learn [2]. In medical imaging efforts have been made to integrate e-learning to the curriculum to show the principles of the imaging modalities, for image reconstruction and image quality improvement [1]. Textbooks or even the hyper-text books provide an active teaching and learning models but having an interactive resource model would be more beneficial for instructors and students [7,13]. The interactive model could help students' motivation, perception and comprehension level.

Recognizing the broad impact of medical imaging education, and how efficiently deliver the concept and application and overcoming the obstacles for teaching and learning caused development of simulation platform for learning and virtually hands on experience with most common medical imaging modalities.

Objective and Methodology

BME department of University of Miami designed and constructed an online teaching system, called "Medical Imaging Teaching Software" (MITS) shown in figure 2 [9,14-18]. The ultimate goal is to develop an online user interactive teaching/learning system, featuring animations and simulations for physical principles, mathematical derivations and engineering implementations, that would fulfill the medical imaging education and simulation research tasks optimally. The project supported by two NSF funding cycles. The MITS could be used for variety of biomedical imaging courses from introductory to advanced level.

Figure 2. The MITS website with five most common modalities.

There are built in teaching modules for each modality that explains the basics and principles. These modules correspond to the physics, math and … principles of modalities and are interactive using animation or simulation. Each of the modules includes historical and background review, text and figure illustration of the basics and principles with interactive animation, interactive and dynamic simulation, demonstration of application, and Dynamic Assessment Tracking System (DATS) to track students' progress. The modules can be terminated by the instructor/ administrator to fit the course objectives, approaches and level of proficiency. Figure 3 shows the system configuration, modalities and modules. Instructor gets instant feedback on the topic delivered through lecture when students work on the system. There are five main medical imaging modalities in MITS (X-ray, CT, MRI, Nuclear Medicine Imaging (NMI), Ultrasound and the Image Processing (IP)).

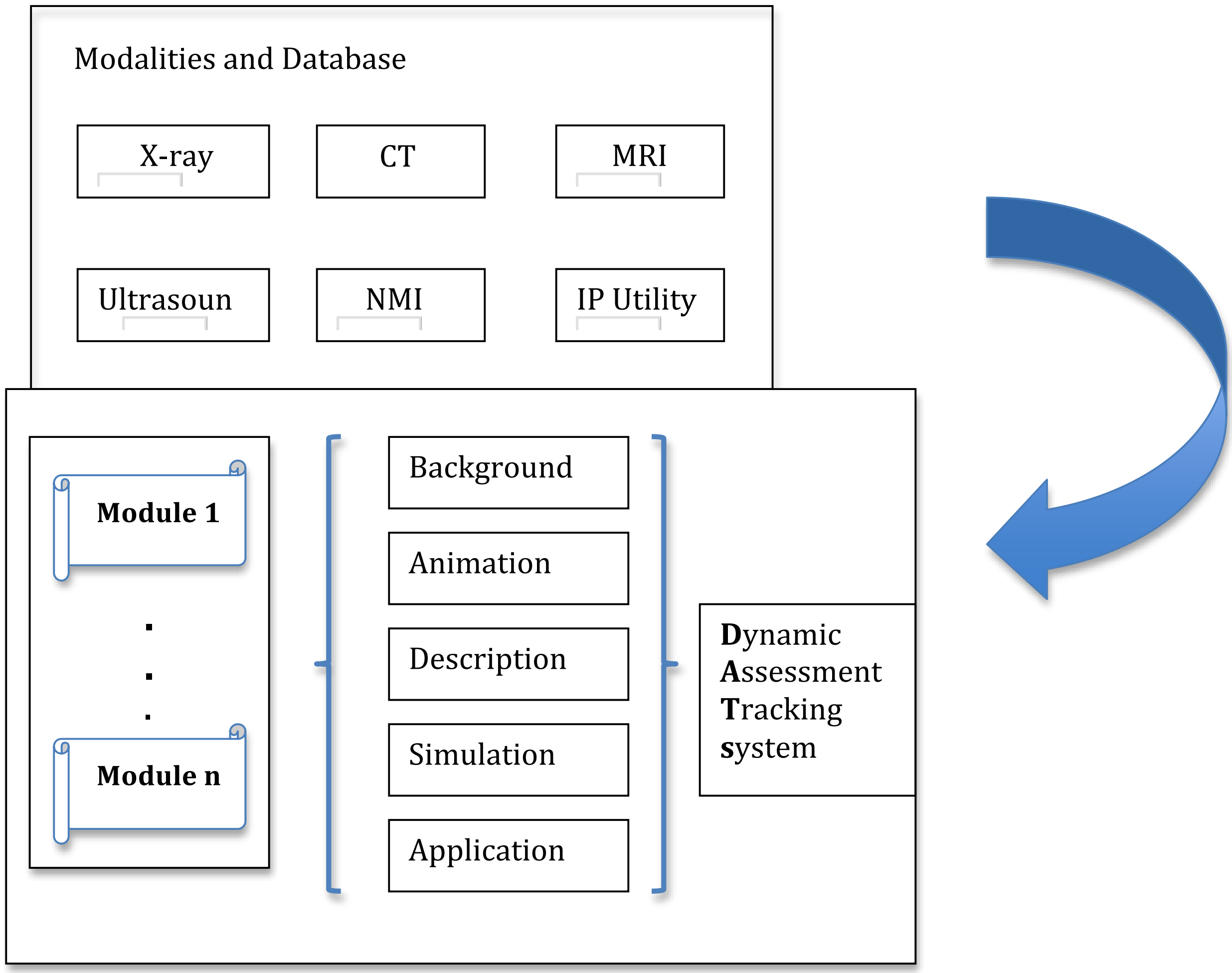

Figure 3. MITS configuration for medical imaging modalities and modules.

In order to manage the modules and collect the feedback of student's performance or engagement with MITS, the DATS is built on and the open source MySQL database software has been integrated. This would help to turn on or off each module by instructor and would allow student's performance on MITS be recorded. For teaching/learning assessment, pre-modality (4-5 questions) and post-modality (10-20 questions) tests, and pre-module (1-2 concept questions) and post–module (3-4 concept questions) are designed. The questions are randomly selected from predefined question pools.

Implementation

Here for the example delivery of the MRI modality is shown. In figure 4 the flow chart for MRI is shown. It shows modality starts with the brief history, review of physics, why do H atom is the main element for this modality, spin, magnetic resonance, magnetic dipole moment, RF pulse and T1, T2 relaxation.

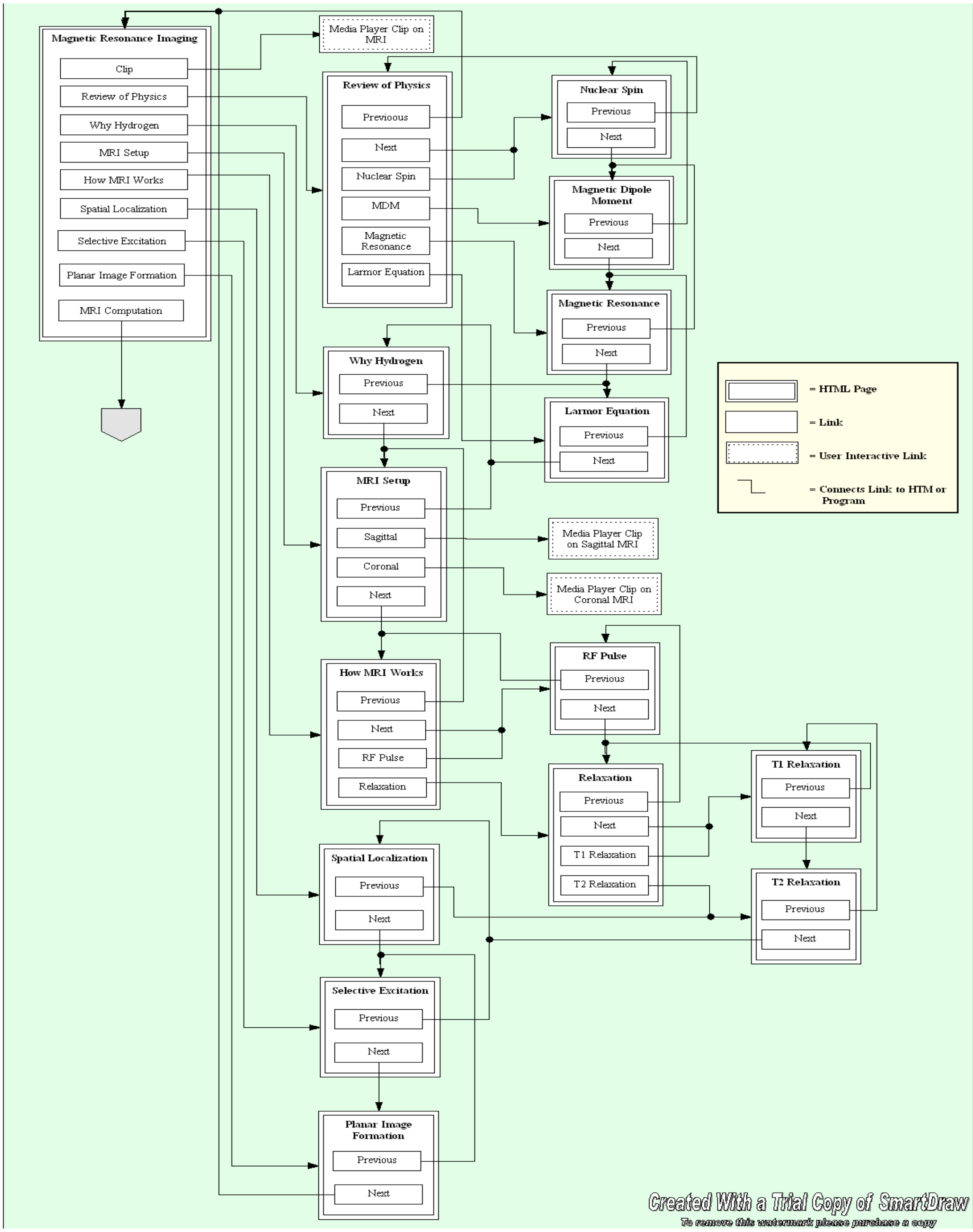

Figure 4. MRI flow chart.

To study the angular moment, precession and Larmor Frequency there is an animation in the module as shown on figure 5.

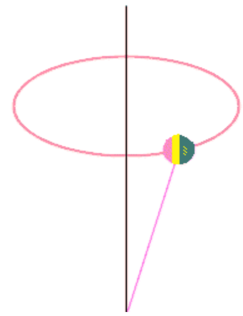

Figure 5. The oscillation of particle with the larmor frequency on xy plane.

Also, atoms that would be monitored during scanning can be changed and the effect of magnetic field on spins of these atoms can be study. There are four atoms in this module H, C, F, P and students can choose either one and study the effect of different magnetic field on those atoms one by one as shown on figure 6.

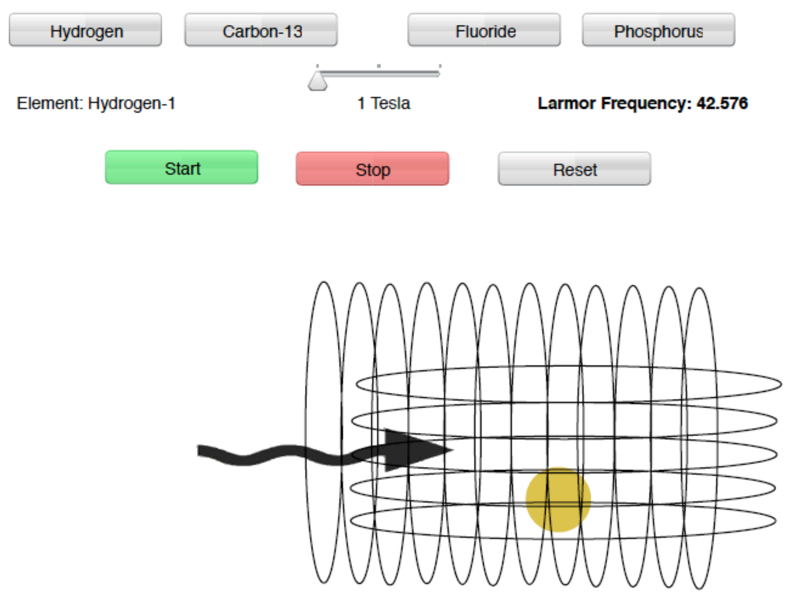

Figure 6. Effect of magnetic filed with different strength on atoms of H, C, F, P.

Radio Frequency pulse, Relaxation (T1 and T2) with animation shown in the figure 7. The strength of the magnetic field can be changes and the effect of this change on on relaxation time can be seen in animation.

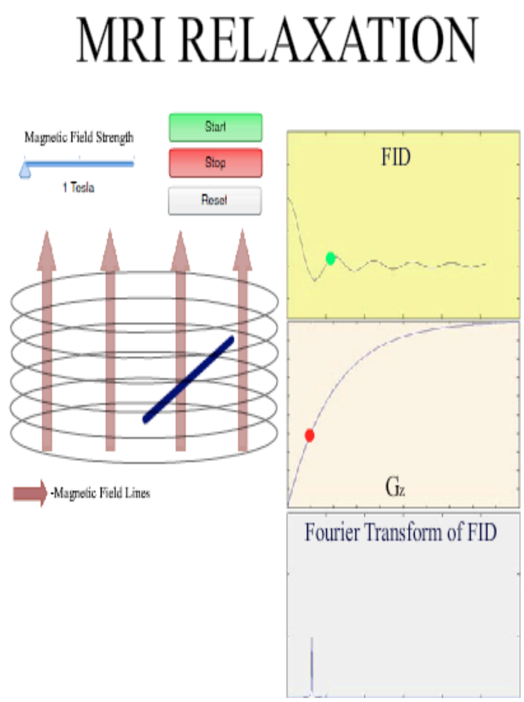

Figure 7. The effect of different magnetic field on atoms and Fourier transformation and relaxation time.

RESULTS

The MITS []system was used for lab session during the summer semester at Wentworth Institute of Technology with 34 students. Students had exposed to the principles of modalities during the lecture time and during lab session used MITS system to have virtual hands on experience with the concept thought during the class and image construction / reconstruction. After several modalities and sessions, students asked for feedback. All the students confirm that there was improvement from the MITS regarding understanding and visualization of principles and basics behind the modalities. Some aspects of the MITS even had better effect on the understanding of the concepts, like Larmor frequency. Even having direct access to the MRI would not help to visualize or see how magnetic field changes the oscillation of the particles. Table 1 shows the data collected during the summer Biomedical Imaging course. The MITS helped to understand the concepts behind the modalities. Students been tested in regards to understanding principles of imaging after the lectures and after the MITS review. The result shows about 24% increase of correct answers. The normalized learning gain [3,4] calculated using the following formula; LG=(Post-Pre)/(100-pre).

Questions	Pre-MITS Correct	Wrong	Post-MITS Correct	Wrong	gain
1	33	1	34	0	1
2	21	13	26	8	5
3	24	10	31	3	7
4	31	3	33	1	2
5	19	15	27	7	8
6	26	8	25	9	-1
7	23	11	32	2	9
8	33	1	31	3	-2
9	18	16	26	8	8
10	27	7	32	2	5
11	20	14	29	5	9
12	31	3	31	3	0
13	18	16	27	7	9
14	24	10	26	8	2
15	16	18	29	5	13

Table 1. Students learning gain for biomedical imaging during summer 2015

In table 2 the time spent on MITS system vs the result of the final grade is shown. From the surveys given to students during and at the end of the semester, more than 80% students gave the positive response for using MITS.

CONCLUSION

Based on outcomes and statistics MITS systems is very good alternative to hands on to modalities of biomedical imaging. There are cases that having direct access to the equipment would not help the understanding of the principles like effect of magnetic field on different atoms, Larmor frequency etc. The result of the surveys and test results shows MITS/DATS system is convincingly proper and applicable for medical imaging courses at different level, but needs some fine-tuning for clear distinctions for different course outcomes and level of complications.

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