

A simulator for teaching MR image contrast behavior

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A computer program to create magnetic resonance images simulating the main features of a magnetic resonance imaging (MR) machine was developed on a personal computer. The simulated MR images are calculated using the relevant equations describing a chosen pulse sequence on the basis of proton density, T_1 and T_2 images acquired from whole-body MR equipment. The imaging parameters (i.e., TR, TE, TI, etc.) are provided by the user. This program produces highly realistic simulated images and includes features such as choice of echo time, inversion time, repetition time and flip angle, as well as standard features of image display programs such as setting of window level/width, zooming and region of interest definition. A novel additional feature is the ability to define artificial pathologies in user-defined areas by specifying changes in the relaxation times and proton density. The simulator has been developed for teaching and training purposes. A prototype version has been used for teaching MRI with extremely positive reactions from students.

Keywords: MRI, continuing education, training, computer simulation.

INTRODUCTION

The mechanisms which influence and change image contrast in magnetic resonance imaging (MRI) are quite complex [1]. Understanding the relationship among image contrast, pulse sequences and sequence parameters is difficult and often requires much intuition and imagination. Therefore, there is a need for teaching tools beyond textbooks and slide presentations.

The best teacher is an MR machine itself. However, learning by experience is time-consuming, expensive and, in cases with human pathology, impossible. Thus, the next best tool is an MRI simulator; a computer program that simulates the images obtained with an MR machine without performing real examinations. This article describes an MRI simulator which runs on inexpensive and easily available computers of the PC family.

DESIGN PRINCIPLES

Cognitive theories and experiments suggest that students learn better and faster when they have the

opportunity of actively participating in the process. In addition, it has been demonstrated that feedback is essential in all teaching situations [2-4]. The reasons behind these principles are beyond the scope of this article but are basically related to learning and cognitive processes [5]. A simulator represents an optimal tool incorporating both principles. First, the student is required to operate the simulator and is thus an active participant. Second, the results of the operations are displayed on the screen and provide immediate feedback to the student.

Thus, the MR Image simulator has been designed according to the following guidelines [2]:

- The user should be in control.
- The response to the user's actions must be as fast as possible.
- It should be possible to reverse all actions with as little effort as possible.
- The program should not allow the user to make serious mistakes.
- The same actions must always lead to the same result.
- The same visual coding used on the screen must always have the same meaning.

Both the preprocessor (described in the next section) and the simulator have been developed using object-oriented methods [6]. The class hierarchies have been designed in a way that makes it easy to

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