Real-Time Spectral Decomposition Imaging: Moving from Minutes to Seconds

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TARGET AUDIENCE

This work will appeal to those interested in real-time and interventional MRI.

PURPOSE

Real-time imaging is useful for many diagnostic and interventional procedures. While the most basic morphological imaging techniques are adequate in many cases, there is an increasing need for more sophisticated imaging techniques. Spectral decomposition techniques like Iterative Decomposition of water and fat with Echo Asymmetry and Least-squares fitting (IDEAL) would be used for real-time tracking of a robotically-controlled ceramic biopsy trocar in the breast [1], or for monitoring the delivery of therapeutic agents tagged with lipid or superparamagnetic iron oxide (SPIO) markers.

A number of imaging platforms are currently under development that insulate software developers from the complications of interacting with scanner hardware. By eliminating closely-coupled and vendor-specific integration throughout the various layers of imaging (data collection, reconstruction, and visualization), these platforms can greatly simplify and speed the development and deployment of new imaging techniques [2,3,4].

MATERIALS AND METHODS

We developed a real-time implementation of the IDEAL water/fat decomposition algorithm [5] on the RTHawk [2] platform (HeartVista, Inc. Palo Alto, CA, USA). Instead of using the native scanner hardware pulse programming language, the acquisition is defined using a pulse sequence definition language, scripts, and real-time bidirectional communication with our interventional software. This structure allows for on-the-fly changes of scan parameters as simple as varying the echo time or as complicated as the changing the entire acquisition trajectory.

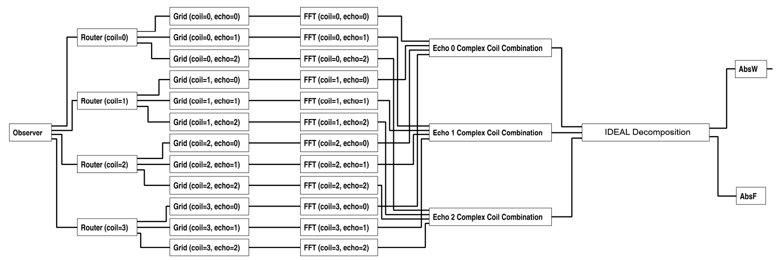

Figure 1: *Image reconstruction is defined as a "pipeline" of processing blocks that operate on "tagged" data emitted by the acquisition. A base set of commonly-used blocks is included with the RTHawk system, and additional blocks are programmed in C++ and integrated through a "plug-in" architecture.*

The real-time reconstruction is simplified by using HeartVista-provided functionality for splitting up data by receiver, gridding, FFT, and gradient unwarping, with our own custom-developed blocks for performing complex coil combination and spectral decomposition. The user interface, visualization, and scan control are written in JavaScript, and the reconstruction pipeline itself is constructed with JavaScript code, but can be visualized graphically, as shown in Figure 1.

We implemented two different acquisitions and used them to image a water/fat phantom on a GE Healthcare Discovery MR750 3.0T scanner (GE Healthcare, Waukesha, WI, USA). The non-Cartesian acquisition is a 2D GRE spiral with five interleaves, 25° flip angle, a 10.7 ms readout, 12.6 ms TR, echo times of 1.0/1.8/2.6 ms, and 24 cm FOV, for an effective resolution of 1.8 mm and a frame rate of ~6 frames per second. The Cartesian acquisition is a 2D FGRE sequence with 256x256 acquisition matrix, 28 cm FOV (1.1 mm resolution), 25° flip angle, ±125 kHz receiver bandwidth, 3 mm slice thickness, TR of 10.4 ms, and TEs of 4.6/5.4/6.2 ms, with each full echo collected on a separate pass, for a total scan time of 8 s per frame. The phantom was an 18 cm diameter plastic sphere containing peanut oil floating on 0.9% normal saline doped with 5 mM $NiCl_2$.

RESULTS AND DISCUSSION

The Cartesian and spiral implementations were both successful in real-time spectral decomposition of the water/fat phantom, as shown in Figure 2. The fat image from the spiral sequence shows a typical blurring artifact due to off-resonance over the long echo time, but the water image is unaffected.

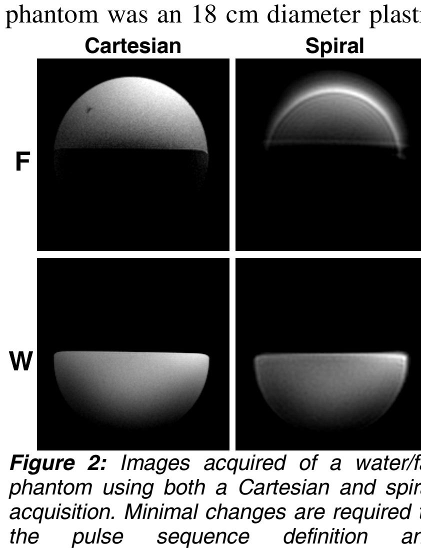

Figure 2: *Images acquired of a water/fat phantom using both a Cartesian and spiral acquisition. Minimal changes are required to the pulse sequence definition and reconstruction script - a total of seven lines of code differ between the two versions.*

CONCLUSION AND FUTURE WORK

While IDEAL has traditionally been used to provide diagnostic volumetric imaging over time intervals of minutes, this real-time implementation allows its use for important interventional applications like monitoring the position of a biopsy trocar in fatty areas of the breast or tracking an endovascular catheter in the challenging B_0 environment of the liver. Building on the modular RTHawk platform allows for clean separation between the software controlling acquisition, reconstruction, and visualization, simplifying changes between acquisitions. In the future we plan to extend this to support a number of higher-echo acquisitions and *k*-space spectral decomposition techniques [6,7].

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