A System for Real-Time HARP-MRI Strain Visualization

K. Z. Abd-Elmoniem¹, S. Sampath¹, N. F. Osman², J. L. Prince¹

¹Electrical & Computer Engineering Department, Johns Hopkins University, Baltimore, Maryland, United States, ²Department of Radiology, Johns Hopkins University, Baltimore, Maryland, United States

Synopsis
We present a system for real-time cardiac strain visualization using FastHARP imaging sequence. The system integrates FastHARP acquisition in parallel with a recently developed rapid strain computation and visualization tool. The marriage of these two components can now provide an update in myocardial strain in a CINE sequence of images once every three heartbeats.

Introduction
The ability to instantaneously detect the onset of an ischemic event is critical to patient safety during cardiac stress exams. A real-time HARP imaging sequence that acquires a sequence of HARP images with tags oriented in a particular direction in a single heartbeat has been implemented [1]. The ability of this sequence to run in a continuous monitoring mode with tags alternating between vertical and horizontal directions in successive heartbeats has also been demonstrated. Although the pulse sequence successfully acquires images in a real-time fashion, the lack of fast strain computations integrated with the sequence has limited its potential use in a clinical stress environment. In this abstract, we present an implementation of a system for real-time scanning, processing, and visualization of myocardial strain.

Methods
Fig. 1 shows a schematic diagram of the system. At the end of each heartbeat, the images acquired by the FastHARP pulse sequence on the host computer during that heartbeat are transferred to a directory in a nearby SUN workstation via a Bit3 Bus adapter. This directory is mounted on the laptop through a 100 Base T Ethernet connection. At the beginning of every experiment, a header file that includes the scanning parameters is generated and stored on the mounted directory. An optimized HARP strain visualization tool [2], coded in C++, resides on a DELL Inspiron 1.9 MHz laptop under RedHat Linux 7.3 and runs in parallel with the pulse sequence. The tool reads this header file, followed by the data from the first pair of heartbeats via an NFS protocol. It then computes a CINE sequence of strain images at a rate of 40ms/time frame. The tool continuously processes data from the most recent two heartbeats and updates the strain images. It also provides a fast implementation of the HARP tracking function. Using this, the time profile of the Lagrangian strain of material points can be obtained at a rate of 8ms/poin.

The system was tested on a 1.5T Signa CV/I whole body MRI system (GE Medical Systems, Waukesha, WI) equipped with 40mT/m imaging gradients with slew rates of 150mT/m/ms. The MR signal was acquired using a 4-channel cardiac phased array coil and receiver system (GE Medical Systems, Waukesha, WI). Data was obtained from a normal 24 year-old female volunteer. An oblique short axis, 10mm thick slice of the left ventricle was prescribed. The FastHARP sequence was run in the continuous monitoring mode for about a minute, and seventeen images of size 32 × 32 were acquired per cardiac cycle with the following scanning parameters: FOV: 40cm, echo train length: 8, views acquired/heartbeat: 32, receiver bandwidth: 62.5 kHz, TR/TE: 9.7ms/2ms. The images were transferred to the laptop and the strains were visualized in real-time.

Results
Fig. 2 shows a snapshot of the visualization tool displaying the Eulerian circumferential strain map overlaid with synthetic tags and the strain evolution of one material point in the posterior-septal region. An end-systolic time frame is displayed in the window (note the bending of the synthetic tags and the dark blue coloration in the strain maps). We found that one heartbeat worth of data was dropped after every two heartbeats that were processed. Further investigation revealed that this was due to the speed limitation posed by the network connection between the SUN workstation and the laptop.

Discussion
In this study, we verified that real-time strain visualization is possible with strain updates every heartbeat. However, due to the slow network connections, strain maps are actually updated once every three heartbeats. Optimization in the software is expected to allow more points can be tracked simultaneously and with faster data transfer, strain maps can be updated without delay.

References

Fig. 1. Connections and data flow between the components of the system.

Fig. 2. A snapshot of the analysis and visualization tool showing the circumferential Eulerian strain map and the time profile of the strain of one of the material points.