MRI Motion Compensation by Positional Ultrasound Biometrics

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Introduction: The method of navigator echoes is one of the most mature techniques for reducing MRI motion artifacts [1]. The technique is well-established, but does have a cost in imaging time, steady-state magnetization, and pulse-sequence engineering complexity. Many alternative technologies have been proposed to provide position information, including 2D ultrasound imaging [2] and 1D ultrasound rangefinding [3]. For this investigation, we have demonstrated a system that uses a single ultrasound transducer to track multidimensional motion, including motion perpendicular to the ultrasound beam.

Methods: The ultrasound transducer we employed was a 5 MHz broadband piston 4 mm in diameter. It produces an approximately collimated "pencil-like" beam. The target was a motion phantom, driven cyclically with a period of 7 seconds by a motor outside the scanner room, approximating breathing motion. The phantom was constrained to move linearly, perpendicular to the ultrasound beam.

The scanner (1.5T GE Signa) executed an SSFP (GE Fiesta) sequence with TR=10ms and TE=1.7ms using the body coil. Phase encoding was disabled, and the frequency encode axis was oriented along the direction of motion. One ultrasound echo was recorded for each MR excitation. During the training stage, 10^4 ultrasound and MR echoes were collected. Positions were determined from the MRI data, and representative ultrasound echoes were selected at 20 equally spaced positions. These 20 ultrasound echoes were stored as a database, each identified by its corresponding position. We term this arrangement a *positional biometric database*.

During imaging, ultrasound echoes were acquired at 100 Hz. Each echo was compared against all 20 entries in the database by a shift-invariant similarity metric implemented using a FFT. The position associated with the most similar database entry was determined to be the current position estimate, and was transmitted to the pulse program via the RTHawk real-time control framework [4]. The pulse program immediately adjusted its parameters to track the new position. Total latency appeared to be less than 12 ms.

Results: This experiment shows that real-time tracking of motion perpendicular to the ultrasound beam works correctly in a motorized motion phantom moving in one dimension. Using an extension of this approach, we have also achieved successful tracking of a motorized phantom that rotates and translates along a curved two-dimensional path, using MRI image registration and regridding.

Discussion: This research is especially motivated by the problem of performing MR-guided focused ultrasound surgery (MRgFUS) in the liver. When the patient breathes, the liver moves several centimeters, approximately along the cranio-caudal axis. This technique could enable MRgFUS treatments in the liver during free breathing, by providing reliable real-time position information from a single transducer placed on the abdomen. Current investigation is directed towards validating this technique in animal models and human subjects, in order to determine its accuracy and effectiveness in more realistic applications.

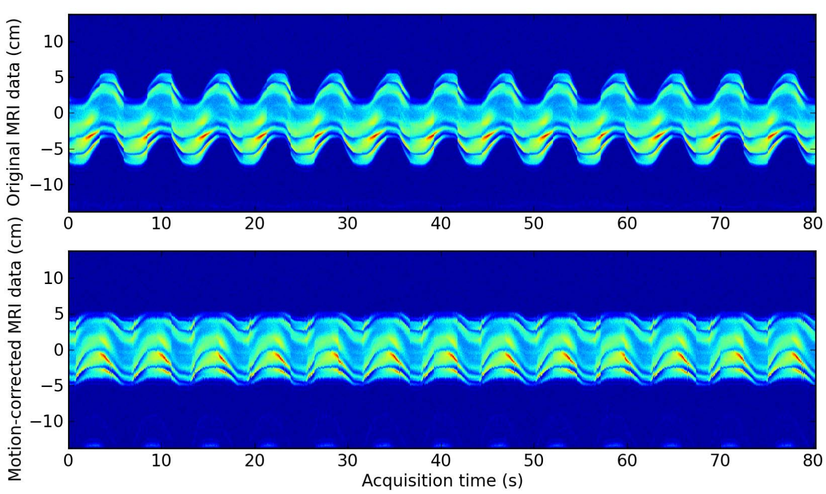

Figure 1: Data from a moving phantom (GE Signa 1.5T, SSFP/Fiesta) over time, with phase encoding disabled. The top image shows the original MRI data, with no correction applied. The bottom image shows motion-corrected data from the same phantom. Patterns within the phantom are artifacts due to B0 inhomogeneities.

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