Hybrid MR-ultrasound acquisition to improve cancer therapy

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Abstract

Magnetic resonance imaging (MRI) is increasingly used for image-guided interventions, such as tumor ablation, needle placement and biopsies, due to its excellent soft-tissue contrast and high SNR. However, the limited size of the scanner bore severely limits physical access to the patient. Furthermore, the magnetic field renders many interventions impossible due to incompatibility of the involved devices. We aim to alleviate these problems by combining MRI and ultrasound (US) acquisitions as well as machine learning techniques, to estimate MR images of abdominal respiratory motion at high frame rate inside and outside the MR bore [1, 2]. The proposed method enables a boost the MRI temporal resolution by an order of magnitude or more. Furthermore, it allows synthetic MR images to be generated even outside the scanner, solely based on the US signal.

In conventional US imaging, an array of transducers is used, often in combination with "delay-and-sum" beamforming [3], for 2-dimensional image reconstruction. There, a large amount of information is discarded during the spatial encoding process, for example to remove signals that have been reflected more than once on their way from the transducer and back. In contrast, in the present work the US signal is obtained from an MR-compatible single-element transducer and no spatial reconstruction is performed. Instead, the ultrasound raw data (USrd) are processed, as a unique "signature" of the abdominal configuration. A database of MR images and USrd pairs was built during a short training phase of about 2 minutes. Based on this learned database, MR images were synthesized based on the similarity between a new, incoming USrd signal and the signals in the database.

Two validation methods were implemented. For validating results inside the scanner, an expert manually annotated the location of prominent structures in both acquired MR images as well as their synthetic counterparts. For validation of synthetic MRI outside the scanner, optically-tracked 2D ultrasound was performed and compared to synthetic MRI. Inside the bore, the average error determined by comparing real and synthetic MR images was roughly 2 mm. Outside the bore, the respiratory phase and amplitude of synthetic MRI was found to be visually very similar to the ground-truth motion obtained from 2D ultrasound imaging. Figure 1 shows a comparison of acquired and synthetic MR images.

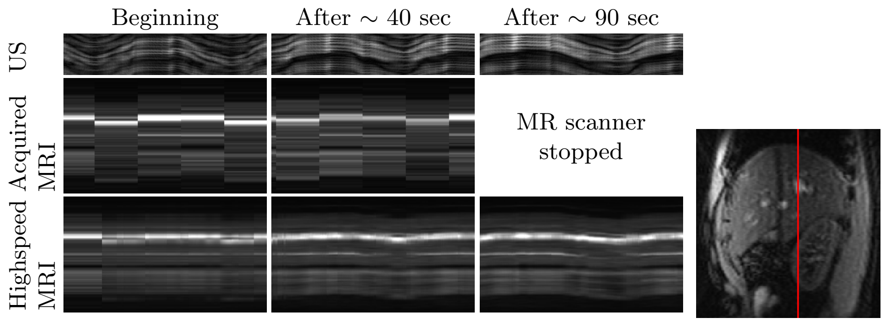

Fig. 1: M-mode visualizations from [2]. The image on the right shows the position of the m-mode line which is plotted over time on the left. The top row shows a visualization of the USrd signal.

References

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