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Meeting abstract

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2094 3D visualization of active catheters using compressed sensing

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Introduction

A crucial requirement in MR-guided interventions is the visualization of catheter devices in real-time. Common tracking techniques rely either on image projections to localize the catheter tip [1] or on single slice imaging [2] to capture the extent of the catheter in parts. True three-dimensional visualisation of the full length of catheter devices has hitherto been impossible given scan time constraints. Compressed Sensing (CS) has recently been proposed as a method to accelerate MR imaging of sparse objects [3]. Since most objects to be imaged are not sparse in the image domain itself, a suitable transform basis is to be found permitting application of the CS method. Active catheters are sparse objects per se and therefore are well suited to the CS framework without requiring any further sparsifying transformation. It is the objective of this work to investigate the feasibility and the limits of CS for visualizing active catheters in three dimensions while satisfying real-time conditions.

Materials and methods

Data acquisition

A high-resolution image volume of the heart and the aorta (resolution 1 mm^3) was acquired on a 1.5 T Philips Achieva system (Fig. 1a) using a 5 element cardiac coil (Philips Medical Systems, Best, The Netherlands). A virtual catheter consisting of a single loop antenna (length 100 mm) was simulated and positioned inside the aorta (Fig. 1b). Sensitivity values of the active device were calculated using Biot-Savart's law. The sensitivity values were multiplied with the in-vivo data to yield a virtual simulation environment based on realistic in-vivo anatomy (Fig. 1c). In CS, scan acceleration is achieved by random undersampling the phase-encode dimensions (Fig. 1d). In this work, the density of random undersampling was varied according to a Gaussian probability function with higher sampling density at the centre of *k*-space for net undersampling factors ranging from 2 – 80.

Data reconstruction

Randomly undersampled data (Fig. 1e) were reconstructed using Orthogonal Matching Pursuit (OMP) as a fast approximation to the L1-norm inversion problem in CS [4]. The known length of the active device to be imaged served as prior to control the number of iterations in the OMP algorithm. Accordingly, only a given number of data points was reconstructed. In order to assess the reconstruction error for varying acceleration factors the mean absolute difference between the true catheter location and the locations of the reconstructed points was determined. For display, reconstructed data were converted into a binary map and overlaid onto the in-vivo images.

Results

The sensitivity map of a single loop antenna shows an almost constant sensitivity along the curvature of the antenna which drops rapidly with growing distance. The reconstruction of the catheter shape was successfully achieved with acceleration factors of up to 35 (Fig. 2, upper right), which facilitates real-time data acquisition in 3D. Fig. 2 (left) depicts the mean absolute error between the reconstructed points and the actual location of the

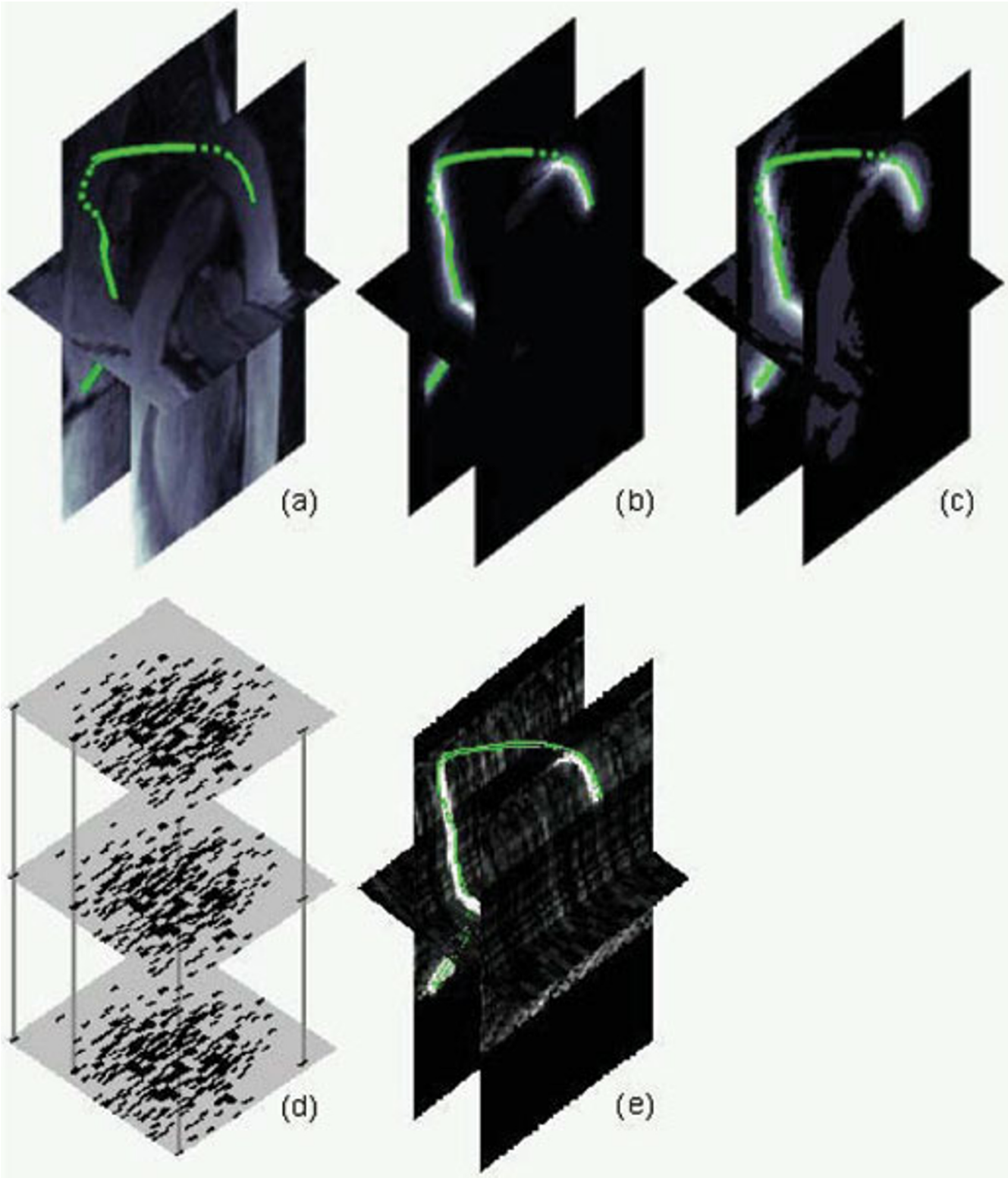

Figure 1
Data acquisition. A high resolution image is acquired and the virtual catheter is positioned (a). The sensitivity map of the antenna is calculated (b) and multiplied with the image (c) Random undersampling (d) leads to the virtually acquired *in-vivo* data (e).

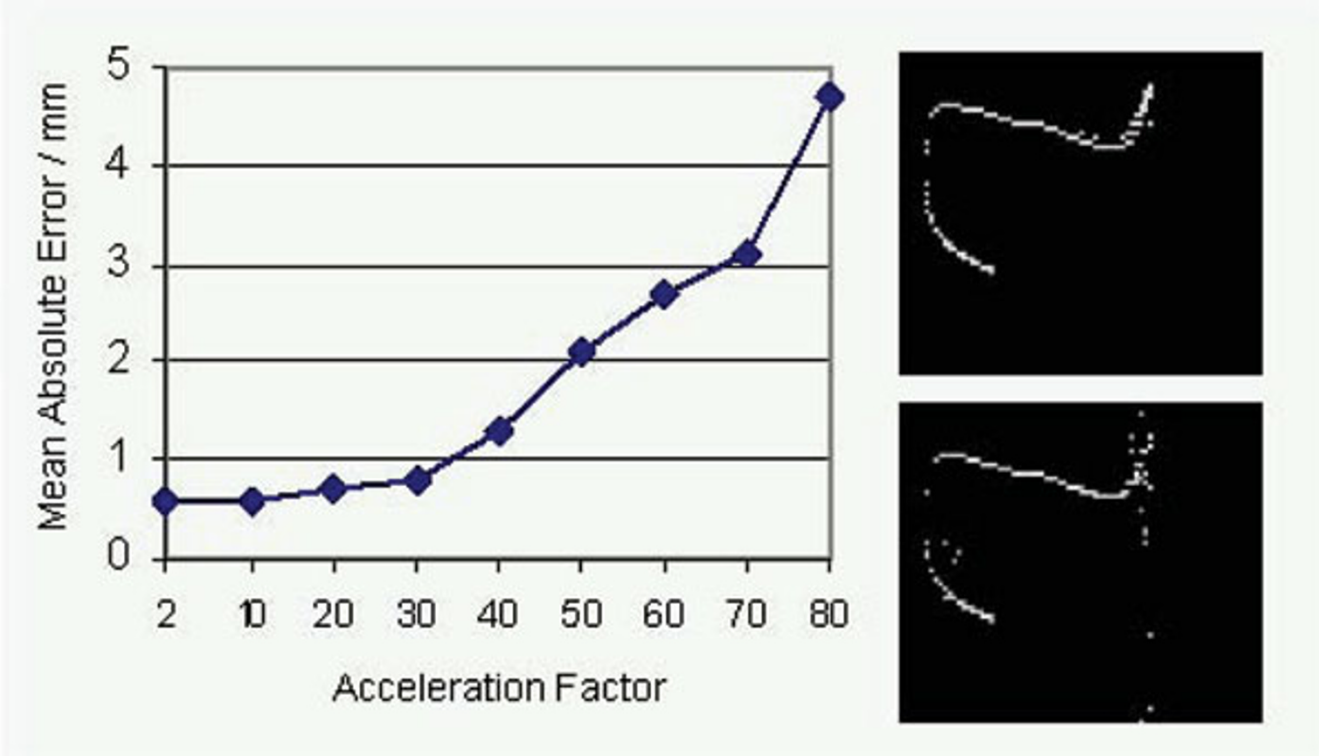

Figure 2
Data reconstruction. Up to an acceleration factor of about 35, the mean absolute error is less than the image resolution (left). Most of the reconstructed points are located along the centreline of the catheter (upper right: acceleration 35, lower right: acceleration 80). Tailored interpolation schemes may be used to recover the true shape even from highly undersampled data.

simulated catheter. Even for acceleration factors greater than 35, the error remains on the order of the image resolution (Fig. 2, lower right).

Discussion and conclusion

Images of active catheters exhibit a high sparsity, which makes these data perfectly suited for CS. Image reconstructions of high quality for undersampling factor of up to 35 have been demonstrated. With a tailored interpolation scheme, using knowledge about the catheter properties, it might be possible to recover the shape even for acceleration factors beyond the current limit of 35. In conclusion, the proposed method shows that 3D imaging of interventional devices under real-time scanning conditions is feasible.

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