Fast Catheter Profiling by Controlled Aliasing

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Introduction

NMR profiling technique [1] has been developed for active visualisation of flexible instrument bodies in the MRI. The profiling coil is sensitive to the NMR signal from its vicinity only, thus it is possible to acquire thick slices i.e. projection images which clearly visualise the instrument.

We have earlier developed an automated method for reconstructing the 3D shape of a profiling catheter in the MR scanner coordinates [2]. The 3D shape can be used in visualising the catheter on top of anatomic images, but more importantly the automated method provides possibility to control the image acquisition according to the catheter location and movements.

Depending on the shape of the catheter two or three projection images are required for the automated 3D reconstruction. Assuming that an image of adequate quality can be obtained within one second, the image acquisition needed for 3D reconstruction takes 2-3 seconds. The other latencies due to scanner calibration, image transfer and processing decrease the practical tracking speed to the level of one 3D reconstruction per every 6 seconds.

The tracking speed of profiling catheter is not acceptable for interactive instrument guidance. We present a method that speeds up the catheter tracking measurement by factor of eight allowing the tracking of the instrument approximately once per second. The method uses controlled aliasing for obtaining reduced field of view imaging of the profiling catheter.

Methods

Catheter tracking has two usage modes during a clinical operation. The visualisation of the full body of the catheter is occasionally needed e.g. after the the catheter is initial introduced into the patient. The visualisation of the vicinity of the instrument tip is required when the instrument is guided towards the target. The speed of the existing automated catheter tracking method is good enough for the visualisation of the full catheter body, but it not acceptable for interactive instrument guidance.

Automated catheter 3D tracking method provides us the catheter location and shape inside the patient. If we use this a priori information, we are able to develop faster approach for catheter tracking during the guidance. Our approach is to apply a reduced field of view (rFOV) technique to image the vicinity of the catheter tip. Several rFOV techniques have been developed for imaging the human anatomy e.g. [3]. However, our problem allows more general and simpler image acquisition scheme for obtaining rFOV images of the catheter.

Since the tracking catheter provides NMR signal from its vicinity only, we can allow signal aliasing, if we can ensure that it does not corrupt the image close to the tip of the catheter. This assumption allows us to use virtually any 2D imaging sequence with a small number of phase encodings. We have got an estimate of the catheter location by using the 3D tracking algorithm, thus we are able to select the directions for slice selection, frequency encoding and phase encoding so that the signal from the rear part of the catheter does not alias to the vicinity of the tip.

Selecting the frequency encoding direction tangential to the tip of the catheter provides the best resolution to the most probable direction of the movement. However, the direction of the phase encoding is the most critical, since the aliasing occurs in that direction. It is straightforward to calculate the best compromise for these two directions for given catheter geometries. Two projection images from different angles are required for obtaining the 3D shape and location of the catheter tip.

We demonstrated the method with an open 0.23T MR scanner (Marconi Medical Systems, Cleveland, USA). We imaged a prototype NMR catheter tracking coil with two field echo imaging sequences (TR = 80ms, TE = 11ms, flip angle = 0.2 degrees) and (TR = 13ms, TE = 5ms, flip angle = 0.2 degrees).

The following number of phase encodings (PE) were tested: 256, 64 and 32. The geometry of the catheter often allows going down to 16 phase encodings, but at the time of measurements we were not able to use such an imaging sequence.

Results

The rFOV images (PE=64 and PE=32) obtained with the first sequence are presented in the top right of the Figure 1. An image obtained with the second sequence (PE=32) is shown in the bottom.

The speed up of the image acquisition has inverse linear proportion to the number of phase encodings, if the calibration prior the scan is not taken in account. The imaging times of each sequence are presented in the images. The faster imaging sequence was at the limits of the stability of our prototype tracking system resulting in corrupted images occasionally.

The aliasing reduces signal to noise ratio approximately by factor square root of two when the number of phase encodings is decreased to half. However, the geometry of the catheter limits the number of the phase encodings before the SNR of the evaluated sequences becomes unacceptable.

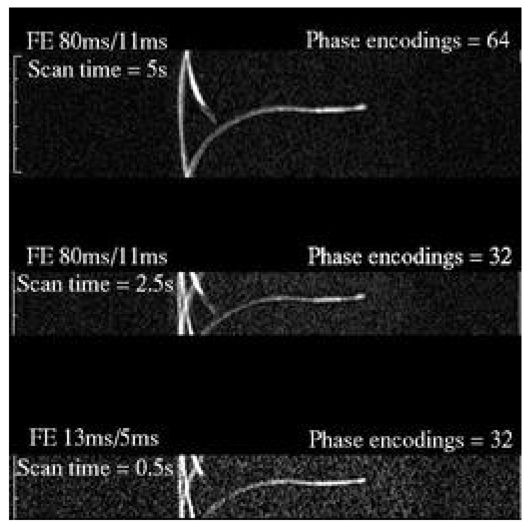

Figure 1. Reduced FOV images.

Discussion

The proposed method provides efficient way for speeding up the active catheter tracking. The controlled aliasing provides upto eight times faster image acquisition. The image processing required for 3D reconstruction of the catheter tip is also much simpler and faster than the one used for tracking the full catheter. We are further developing the proposed method for on-line demonstration with the MR scanner.

References

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