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Data rebinning based decoupling of pFOV overlap scanning in magnetic particle imaging

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Abstract

Magnetic particle imaging (MPI) is rapidly developing as a novel biomedical imaging technique. Due to the safety constraints of bioelectromagnetic stimulation, the partial Field of View (pFOV) scanning approach has been widely used in MPI devices towards small animals and human scales. pFOV scanning has variable degrees of overlap between neighbouring pixels, which may lead to signal aliasing and blurring on harmonic imaging by Fourier transformation. In this paper we propose a data rebinning method for decoupling overlap scanning under a continuous pFOV scanning process. The results show that data rebinning as a digital signal preprocessing technique has the potential to improve the spatial resolution of imaging.

I. Introduction

Magnetic particle imaging (MPI) has shown great potential as a new biomedical imaging modality for applications such as stem cell tracking and small animal imaging[1]. Due to safety limitations of bioelectromagnetic stimulation, there are constraints on the amplitude of high-frequency alternating magnetic field.

The partial field of view (pFOV) scanning adds the focus field for multiple small pFOV scanning, thus expanding the FOV. The processing of signals obtained from pFOV scanning in the frequency domain[2,3] and time domain[4,5] has been studied a lot. The pFOV overlap scanning technique can help to eliminate certain edge artifacts during reconstruction based on the system matrix. However, during time-domain reconstruction, overlapping regions between adjacent pFOVs are inevitable in the reconstructed results. This overlap between pFOVs may lead to signal aliasing.

In this paper, we propose a data rebinning method for pFOV continuous scanning trajectory, aiming to decouple the signal aliasing generated by the overlap scanning of neighbouring pixels by field free region(FFR).

II. Theory

II.I. pFOV scanning

The pFOV excitation field in this paper consists of a triangular waveform field $H_1(t) = A_1(\frac{2t}{T}-1)$ and a sinusoidal waveform field $H_2(t) = A_2 sin(2\pi f t)$:

$$H_{pFOV}(t) = A_1(\frac{2t}{T}-1) + A_2 sin(2\pi f t),\ t \in [0,T] \quad (1)$$

where the range of t is constrained to be [0,T], limiting the FFR to uniformly move from the leftmost to the rightmost side of the FOV.

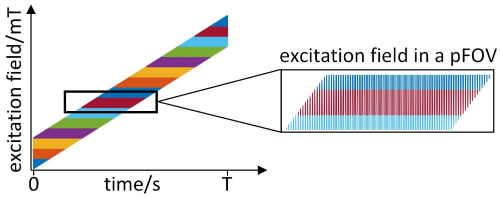

Figure 1: pFOV excitation field and the division of pixels by spatial location. The excitation field within a pFOV is shown magnified.

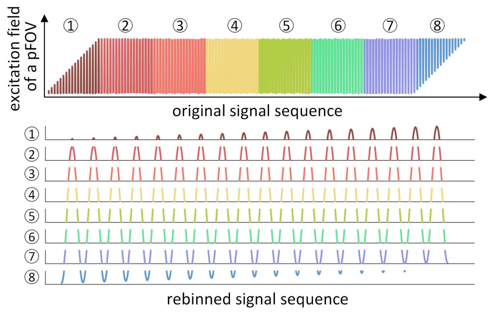

Figure 2: Excitation field within a pFOV, and a schematic of the data rebinning. The excitation field is divided into segments that are re-concated into complete cycles.

II.II. Data rebinning

The field strength of excited field determines the position of FFR. the FOV is divided into equally spaced pixels, and the signal on a pixel passed by FFR is extracted based on the excitation field, as shown in *Fig. 1*.

Under the trajectory studied in this paper, the FFR repeatedly oscillates to scan the same pFOV while moving forward at low speed. The excitation field at a pixel can be rearranged into a complete excitation cycle as shown in *Fig. 2*. Similarly, the received signal is also rearranged.

III. Experiments

We carried out 1D simulation experiments by placing a delta-sample in the centre of the FOV to verify the decoupling ability of data rebinning. The magnetization response of particles is based on the Langevin model, with $A_1 = 15$ mT, $A_2 = 5$ mT, and $f = 1$ kHz. The size of the FOV (Field of View) is 30 mm and is divided into 1 mm pFOVs (partial Fields of View). A magnetic field gradient of 1 T/m is selected.

IV. Results

The results are shown in *Fig. 3*, "raw signal" is the original signal and "rebinned signal" is the signal after data rebinning. The envelope of the signal becomes narrower after processing.

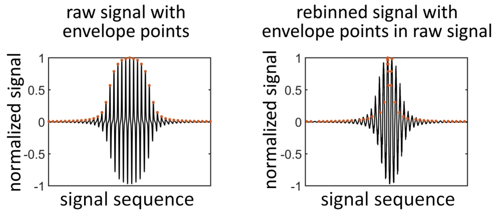

Figure 3: Raw signal and rebinned signal. The second row shows the peak points of the envelope of the raw signal and the timing positions of these peak points after rebinning.

It should be pointed out that signals undergo data rebinning only to be adjusted in timing position, not to add or delete signals. We extract the peak points on the envelope of the raw signal, and after data rebinning, these points are aligned in the middle part of the signal. This indicates that the repeated oscillations on neighbouring pixels during pFOV scanning are decoupled in spatial location.

V. Conclusion and discussion

The data rebinning method is dedicated to decouple the signal aliasing caused by overlap under pFOV excitation. Further, reconstruction based on rebinned signal is expected to improve the spatial resolution of the image. In the future, we will compare the reconstruction results of the data rebinning method with x-space gridding. It is hoped that our work can provide helpful ideas for understanding MPI signal processing.

Author's statement

Conflict of interest: Authors state no conflict of interest. Informed consent: Informed consent has been obtained from all individuals included in this study.

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