A motion tracking method applying spread spectrum communication to tagging MRI

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Introduction:

The tagging cine magnetic resonance (MR) imaging method is commonly used for the detailed analysis of myocardial wall motion, and this method can be used to evaluate the motion of the myocardium comprehensively and noninvasively [1]. The spatial modulation of magnetization (SPAMM) method labels the tissue magnetically using a gradient magnetic field and radio frequency (RF) pulse, and generates a parallel black line in MR images [2,3]. By analyzing the motion of these lines on a time series of images acquired by the cine MR imaging method, myocardial wall motion can be traced in detail. Post-processing using lattice pattern fitting of tagging cine MR images is generally employed for the assessment of tissue motion. The image analysis procedure includes the extraction of target tissue and the position detection of the tagged patterns. We propose a new motion tracking method that codes the position information of tissue on a pixel-by-pixel basis by using a tag pattern, and we test the method with a phantom experiment. The technique for coding the position exploited in this method is based on spread spectrum communication by regarding the tag patterns as digital codes.

Materials and Methods:

In the spread spectrum communication technique, a narrowband signal is modulated to a broadband signal and transmitted using a pseudo noise code. It is demodulated into the original narrowband signal by a receiver. The M-sequence is one of the pseudo noise codes used for spread spectrum communications [4,5]. In this study, 7-bit M-sequences were used as the spread spectrum pseudo noise code and the pixel position was encoded by the seven tag patterns (Fig.1). Cine images of a section are acquired with seven types of tag patterns which are equivalent to a 7-bit M-sequence. All the experiments were conducted on a 1.5 Tesla MRI (Siemens). MR imaging was performed using a segmented fast low angle shot (FLASH) cine sequence with SPAMM preparation pulses. The sequence parameters of the segmented FLASH cine imaging were as follows: FOV=256×160mm, Matrix=256×160 (Pixel size=1.0×1.0mm), Slice thickness=5.0mm, TR=72ms, TE=6.1ms, Flip Angle=20deg, Segment number=5, Band Width=195Hz/pixel. The number of cine phases was 33 and the temporal resolution of a reconstructed image is 36ms. The seven SPAMM tag patterns were generated by adjusting the flip angle and phase of the RF pulses and the gradient magnetic field strength. In order to demonstrate the performance of the proposed method, a verification experiment was conducted using a stationary phantom and a moving phantom. A sinusoidal motion in one dimension was chosen as the moving phantom for simplicity, and the coding procedure of the M-sequence and tag patterns was also made only in the motion direction. The proposed method was compared with the conventional method of tagging images. To observe the reduction of tag contrast as the cine phase progresses, a horizontal strip on the phantom signal was extracted from each cine image and arranged from the first phase at the top to the last phase at the bottom.

Results:

In the stationary phantom experiment, the seven average image provided more distinct tag patterns at later phases than the single average image. The ability to identify the pixel position of the proposed method was comparable with the conventional seven average image (Fig.2). And the performance of the proposed method was comparable to the binarized images of seven average image using Otsu's method [6]. In the moving phantom experiment, the proposed method successfully decoded the tag position on a pixel-by-pixel basis until the 13th phase (Fig.3). Although a conventional tagging image with a 6-mm tag width also showed the motion of phantom until 13th phase, the spatial resolution for motion detection is much lower than proposed method. On the other hand, a conventional tagging image with a 2-mm tag width provided the same spatial resolution for motion detection as the proposed method, but the tag contrast disappeared rapidly.

Discussion:

In this study, we applied the spread spectrum communication technique to tagging MR images. 7-bit M-sequences were used as the spread spectrum pseudo noise code and the pixel position was encoded by the seven tag patterns. For a stationary phantom, the proposed method showed the same ability to identify the pixel position as the conventional tagging method using improved SNR images with seven average acquisitions. The pixel position was successfully decoded by the proposed method on a pixel-by-pixel basis for the moving phantom. However, a clear limitation of the proposed method is the requirement of multiple image acquisitions. Since the number of image acquisitions required for the method is equal to the number of encoding bits, seven image acquisitions were performed to implement the spread spectrum communication technique with 7-bit M-sequences in the case presented in this study.

References:

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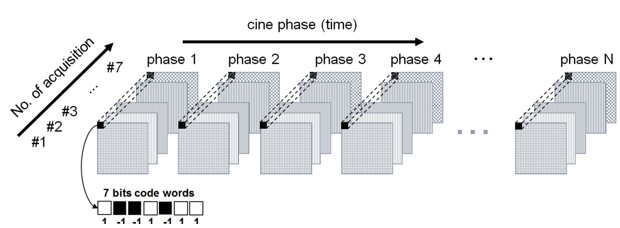

Fig.1 Image acquisition scheme of the proposed method. Cine images of a section are acquired with the seven types of tagging patterns which are equivalent to 7-bit M-sequences.

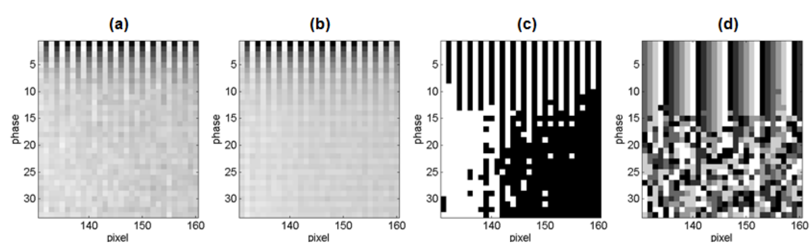

Fig.2 Temporal change of tag contrast in the stationary phantom of short T1 and the result of the proposed method. (a) Temporal change of tag contrast in single average image. (b) Seven average image. (c) Binarized images of (b). (d) Results of the proposed method.

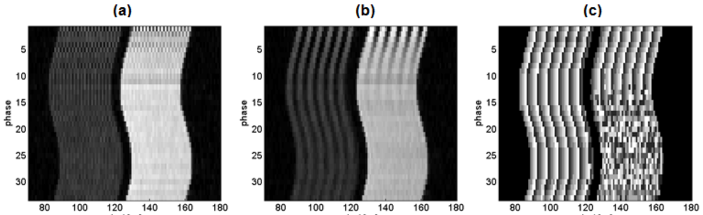

Fig.3 Temporal change of tag contrast in the moving phantom and the result of the proposed method. (a) Moving phantom with sinusoidal amplitude of ± 3 mm. (b) Moving phantom with sinusoidal amplitude of ± 6 mm. (c) show the results of tag positions analyzed with the proposed method. In each figure, the left-hand phantom has a long T1, and the right-hand phantom has a short T1.