Localization of Motion Artifact

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INTRODUCTION

In conventional Fourier transform imaging, a non-stationary object such as a moving object causes a motion artifact (1). Normally motion artifacts spread out whole image domain since the Fourier transform can not provide time information of the moving object. Short time Fourier transform or windowed Fourier transform could provide both time and frequency information at transformed domain (2). Using the time-frequency information, we investigate the localization of motion artifacts to reduce the artifacts due to local motion in an object in MRI. In this paper, a pulse sequence for reconstruction of windowed Fourier transform is proposed and is applied to an object having a local motion. Computer simulations and experiments are performed to demonstrate the reduction of motion artifacts.

THEORY

Windowed Fourier transform

Figure 1 shows a pulse sequence for windowed Fourier transform. A window in image domain is selected by band limited RF pulse (90 degree) and a gradient (x-direction). A windowed Fourier transform is performed using a incrementally changed gradient after the 90 degree RF pulse as shown the figure. After 180 degree RF pulse with slice selection gradient (z-direction), an echo signal can be obtained as

$$S_p(\omega_x,\omega_y)=\iint \rho(x,y)w(x-x_p)\exp(-j\omega_x x)\exp(-j\omega_y y)dxdy\ , \qquad [1]$$

where ω_y is $\gamma G_y t$ for reading direction, ω_x is $\gamma m g_x T$ for coding direction at the window $w(x-x_p)$, p is window number, G_y is reading gradient strength, g_x is one increment of coding gradient, T is the time duration of coding gradient, and m is an integer from 1 to M which is window size. For simplicity, let us consider one dimensional signal in coding direction and Eq. [1] can be rewritten as

$$S_p(\omega_x)=\int \rho(x)w(x-x_p)\exp(-j\omega_x x)dx\ . \qquad [2]$$

Window number, p is numbered from 1 to N/M where N is image matrix size. Reconstruction in windowed transform is performed as the following

$$p(x)=\sum_{p=1}^{p=N/M} F^{-1}\left[S_p(\omega_x)\right] \quad =\sum_{p=1}^{p=N/M}\rho(x)w(x-x_p)\ . \qquad [3]$$

Localization motion artifacts

Moving object is assumed to be localized at x_0. Then the object signal can be written as

$$\rho(x,t)=\rho_s(x)+\rho_m(x,t)rec(\frac{x-x_0}{d})\ , \qquad [4]$$

where $rec(\frac{x-x_0}{d})$ indicates moving region with center of x_0 and moving distance of d. In conventional Fourier transform MRI, local motions in the object cause artifacts. Artifacts spread in all image domain so that even static parts suffer from the moving artifact. In windowed Fourier transform, however, the artifact caused by local motions can be localized and static parts can be free from the moving artifacts.

MRI signal obtained by windowed Fourier transform can be written as

$$S_p(\omega_x)=\int\{\rho_s(x)+\rho_m(x,t)rec(\frac{x-x_0}{d})\}\,w(x-x_p)\exp(-j\omega_x x)dx$$
$$=\int\rho_s(x)\,w(x-x_p)\exp(-j\omega_x x)dx$$
$$+\int\rho_m(x,t)rec(\frac{x-x_0}{d})\,w(x-x_p)\exp(-j\omega_x x)dx\ . \qquad [5]$$

In second term in Eq. [5], moving signal of $\rho_m(x,t)$ is varying during phase encoding so that it causes artifacts. Since Fourier transform is performed within a window as seen in Eq. [2], the artifacts are localized. As far as the window function of $w(x-x_p)$ does not contain the moving parts, second term in Eq. [5] can be negligible. Even if moving part is located within the window, the artifact does not spread in all image domain.

RESULTS AND CONCLUSION

Experiments were performed with a static phantom and moving tube. A moving tube is located aside of static phantom and is forced to move randomly during data acquisition. Image matrix size was 256 and was divided into 4 segments. Window size in windowed Fourier transform was 64. As shown in Fig. 2(a), a motion artifact degraded static part in coding direction around the moving tube for conventional Fourier transform reconstruction. In windowed Fourier transform reconstruction technique, however, the artifacts were localized around moving tube so that the static part did not affected by motion artifact as shown in Fig. 2(b).

In conclusion, we proposed a reconstruction technique using windowed Fourier transform or short time Fourier transform and applied the proposed method to the reduction of local motion artifacts. Since the proposed method provides the time-frequency information, it can be applicable in imaging of non-stationary objects.

REFERENCES

1. Y. M. Ro, Z. H. Cho, MRM., 29, 660-666, 1993.
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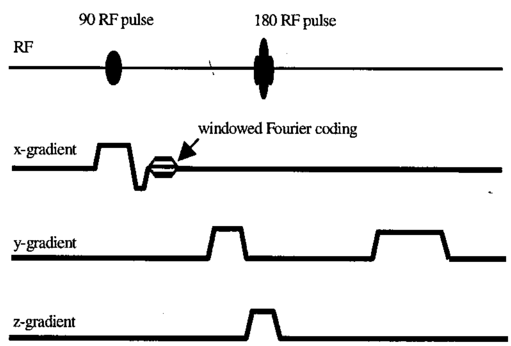

Figure 1. A pulse sequence for windowed Fourier transform.

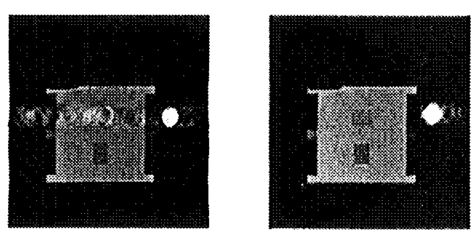

Figure 2. (a) Image obtained by conventional Fourier transform. (b) Image obtained by windowed Fourier transform.