Improved Translation Correction Applied to PROPELLER Using Expansion-matching Filter

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Introduction

PROPELLER is robust to rigid body motion with the capability of estimating rotation and translation shifts of each blade. A template is identified and localized in rotation-corrected blades by matched filtering, a common technique used in pattern recognition, which is to find the most correlated position with the template. The matched filter maximizes the signal to noise ratio (SNR) of the filter response at the true location (usually the response peak), without taking into account the off-peak response. Therefore, the matched filter is sensitive to noise, occlusion, and superposition conditions, such that the template location may be difficult to estimate accurately. Rather than employing the matched filter, an expansion matching (EXM) filter [1] is designed to maximize discriminative SNR (DSNR), which considers the influence of off-peak responses, yielding a sharp matching response peak at the true location so as to overcome the drawbacks of the matched filter.

Method

For a given template *f*, the EXM filter in k space is defined as (1), where $\overline{F}$ is the complex conjugate of the Fourier transform of the template, and γ is a parameter dependent on noise level, which is statistically estimated across all blades. After the EXM filter is applied to each blade in k-space, the response signal $\boldsymbol{Z}$ is obtained by taking inverse 2DFFT, the maximum of Z indicating the template location. Since the EXM filter optimizes DSNR, defined as (2), it assumes all response signals except the template location (x_0, y_0) are noise. The EXM filter depresses off-center response signal in an optimal way, yielding a sharp peak such that location estimation is more accurate than using the matched filter. Images are obtained with a phantom data positioned in a head coil (TR/TE = 1000ms/110ms, ETL=28, matrix size=256×256, slice thickness=5mm) and with a volunteer in an 8HR brain coil (TR/TE=5000ms/110ms, ETL=24, matrix size=480×480, slice thickness =5mm), both of which were collected on a 1.5T GE Signa scanner. For this study, the phantom was moved horizontally such that half of the blades were in a different location, and volunteers were asked to shake their heads randomly.

$$EXM(k_1, k_2) = \frac{\overline{F}(k_1, k_2)}{|F(k_1, k_2)|^2 + \gamma^2} \quad (1)$$

$$DSNR = 10\log\frac{Z(x_0, y_0)^2}{\sum_{i \neq x_0}\sum_{j \neq y_0} Z(i, j)^2} \quad (2)$$

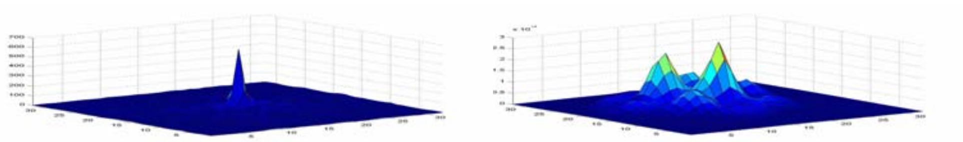

Figure 1. The magnitude of response signal using the EXM filter (left) and the matched filter (right)

Results

Figure 1 shows the magnitude of response signals using the EXM filter and matched filter for a phantom whose images appear in figure 2. The response of the EXM filter has one sharper peak (left) indicating the template location, while the matched filter has a broad response with multiple peaks (right). Figure 2 compares the images reconstructed using the two filters with the same raw data. The reconstructed image (left) using the EXM filter has sharper edges (blue circles) with significantly less motion-derived ghosting (red circles). Figure 3 shows the reconstructed images with either filter in a volunteer scan. The longitudinal fissure is aligned more accurately using the EXM filter.

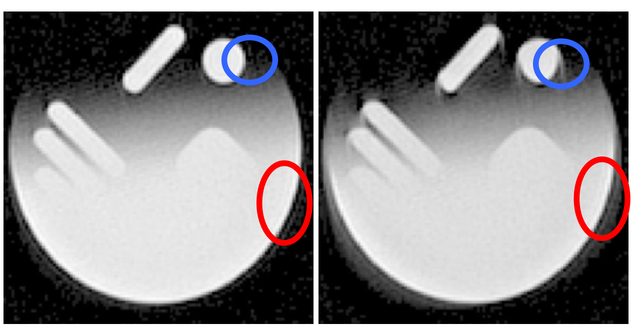

Figure 2. The reconstructed image using the EXM filter (left) has sharper edges (around the blue circle) and less motion artifacts (in the red circle) than the one using the matched filter (right).

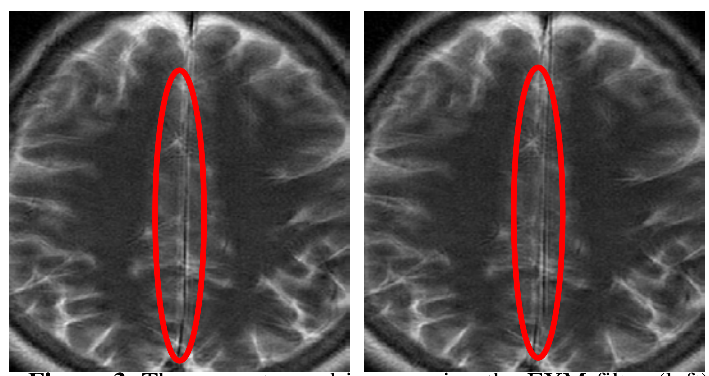

Figure 3. The reconstructed image using the EXM filter (left) aligning the longitudinal fissure (in the red circle) is better than the one using the matched filter (right).

Conclusions

We recommended to applying the EXM filter to propeller translation motion correction, which is capable of estimating the template position more accurately than the matched filter, thus yielding better image quality in multiple phantom and volunteer tests. The EXM filter was also designed to adapt to the noise level in images, resulting in accurate estimation even in noise conditions.

Reference: [1] D. Nandy and J. Ben-Arie, IEEE Trans. on Image Processing, vol. 8, no. 1, pp.22-32, January, 1999