# Motion Estimation for PROPELLER MRI Using Image-Based Registration

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## Introduction

In PROPELLER MRI [1] rigid in-plane motion can be estimated from the repeatedly sampled, disk-shaped k-space centre and corrected as a post-processing step before image reconstruction. However, the standard PROPELLER correction algorithm, as proposed in Ref. [1] successively rotates the disk images in the k-space domain by a series of angles to find the optimum rotation angle, which may be computationally expensive. In addition, empirical weighting of the data may be required to remove the strong concentration of signal in the centre of k-space, and hence, to improve the robustness of the approach [1].

In the present study, a fast image registration library based on Gauss-Newton optimization [2] was used to determine in-plane rigid motion parameters from motion-corrupted PROPELLER data in the image domain. The performance of the library was investigated with respect to image quality and computational speed.

## Methods

*Experiments*

Measurements on normal volunteers and on moving phantoms were performed on a clinical 3 T scanner (Achieva, Philips Medical Systems, Best, The Netherlands) equipped with a software patch for PROPELLER acquisition [3]. Motion corrupted data sets were acquired using a TSE PROPELLER sequence (TR/TE = 3000/80 ms, matrix/TSE factor/blades = 256/24/17). In the phantom experiments, a stepping motor driven phantom holder performed a continuous oscillatory rotation (maximum elongation: 20°, period = 10s). In the in-vivo experiments, data were acquired in transversal orientation, while the volunteer moved his head. For comparison, additional PROPELLER acquisitions were performed in the absence of motion. Image registration and reconstruction was performed offline, using dedicated software on a 2GHz Pentium computer.

*Image Registration and reconstruction*

For each blade, the central k-space circle was zeropadded to a 64×64 matrix and Fourier transformed to the image domain (Fig.1a,e), in the following referred to as disc images. To determine a reference image for registration, all disc images were rotated according to their nominal rotation angle. The cross-correlation for all pairs of rotated disc images was determined and the blade with the best average correlation to all other blades was chosen for reference. For image registration, the cross correlation function was chosen as similarity measure. This may be formulated as a least-squares optimization problem, which can be solved by iterative Gauss-Newton optimization [2]. From the gradient of the cost function with respect to the motion variables an estimate of the motion vector was determined, which was used to reformat the image and calculate a new estimate. The algorithm stopped, when the change of the cost function fell below a certain threshold, i.e. the optimum was reached. For the first iteration, the nominal rotation angle of the blade was used as starting estimate. In image reconstruction, the estimated motion parameters were used for motion correction. For comparison, additional images were reconstructed neglecting motion.

## Results and Discussion

The Gauss-Newton algorithm took at maximum six iterations to register a disc image to the reference image. Image registration for a full PROPELLER data set including selection of the reference image took 50 ms. Selected examples are shown in Fig. 1. In both phantom and in-vivo experiments the motion correction worked reliably and resulted in good image quality. To study the accuracy of the approach, disc images from the static phantom experiments were registered using wrong starting estimates. In this case, the algorithm found motion vectors very close to the true position, which corresponded to displacements far below the mm range. This indicates a high accuracy of the algorithm. In contrast to existing techniques [1] the proposed approach works entirely in image space, which facilitates motion detection on a specific ROI, if only parts of the object move like a rigid body.

In principle, optimization methods that rely on derivatives of the objective function may be unable to find any optimum at all, or multiple local optima may exist. Hence, there is no guarantee that a derivative-based method will converge to the global optimum. However, this problem has not been observed with the current approach so far, which may be due to the characteristically low resolution of the disc images.

In conclusion, the proposed approach represents a fast, accurate and robust technique for estimating motion in PROPELLER MRI. The underlying optimization algorithm operates entirely in the spatial domain, which potentially increases performance and versatility compared to existing approaches [1].

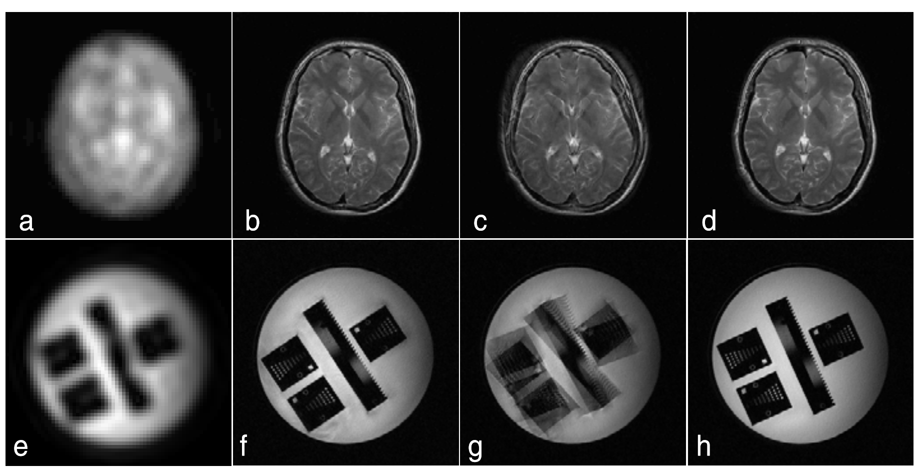


**Figure 2: PROPELLER Motion correction**. In-vivo (top) and phantom (bottom) images are shown. Motion estimates derived in image domain (a, e) were used for motion correction in image reconstruction (b, f). For comparison, additional images are shown, which were reconstructed without motion correction (c, g) or acquired in the absence of motion (d, h), underlining the good image quality achieved with the proposed approach. In (f) minor flow artifacts are visible as a result of the continuously moving phantom.

## References

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3. Welch B. Proc. ISMRM 2006; p.3207