Analysis and Refinement of PROPELLER MRI Motion Correction

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INTRODUCTION: It has been shown [1,2] that PROPELLER MRI provides effective compensation for patient motion. This compensation is made possible through repeated acquisition of the center of k-space (see figure 1) that makes PROPELLER a self-navigating sequence. While experience has shown the existing estimation algorithms to be effective in producing clear images with reduced motion artifacts, an analysis of the validity of the motion estimates has not been published. This work attempts to analyze the existing algorithms, make minor algorithmic improvements, and to correct for known errors.

METHODS: High resolution (512x512, FOV=24cm) FSE data were collected. PROPELLER data were then simulated from the FSE data using a modified DFT algorithm based on the PROPELLER trajectory. Known levels of bulk rotational and translational motion were added as part of the simulation. The estimates obtained through the motion algorithms were then compared to the known levels of motion to determine any discrepancy.

In addition to analyzing the estimates, we implemented and analyzed the following changes to the existing algorithms:

1) Expansion of region of estimation: It was proposed that expanding the "region of estimation" to include areas of incomplete blade overlap would improve estimates (figure 1).

2) Use of local correlation maxima: The rotational motion estimate was taken as the peak correlation value closest to the expected blade angle, rather than the overall peak correlation value, in order to eliminate spurious rotational motion estimates (see figure 2).

3) Enhanced correlation process: The resolution of the correlation was increased and gridding errors were decreased in an attempt to improve the resolution of the estimates.

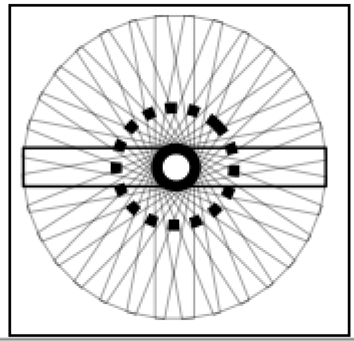

Figure 1: The existing motion estimation algorithm utilizes the central region of k-space (solid circle); expanding the radius of this "region of estimation" (dashed circle) allows for the introduction of higher spatial frequency data.

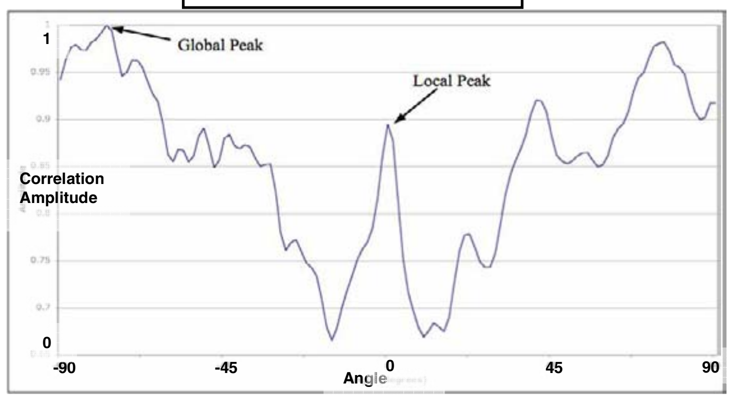

Figure 2: In order to eliminate spurious rotation estimates, the correlation peak closest to the expected blade angle (local peak) is utilized instead of the overall correlation peak (global peak).

RESULTS: The RMS estimation error from the simulated data set is given in table 1 (averaged across blades) for the existing and modified algorithms. These results demonstrate the ability of the motion algorithms to estimate translational motion to within one-tenth of a pixel (512x512 pixels) and rotational motion to within a few hundredths of a degree. The proposed modifications had the following results.

1) Expanding the "region of estimation" provided no improvement in motion estimates and instead resulted in significant degradation of the estimates.

2) The use of local correlation maxima produced the desired elimination of spurious estimates as is demonstrated in figure

3) The resolution of the motion estimates was improved, at the cost of higher computational complexity, by using a higher resolution correlation and reducing gridding errors (table 1).

The simulated data were corrected using the known motion values, the estimated values from the existing algorithms, and the estimated values from the modified algorithms. A visual comparison of the resulting images indicated no discernible differences between the three cases, suggesting that the algorithms are able to estimate bulk motion to within practical equivalence of the actual motion.

Table 1: Average RMS estimation error

Metric	Existing Algorithm	Modified Algorithm
RMS translation discrepancy (pixels)	0.0667	0.0216
RMS rotation discrepancy (degrees)	0.0242	0.0197

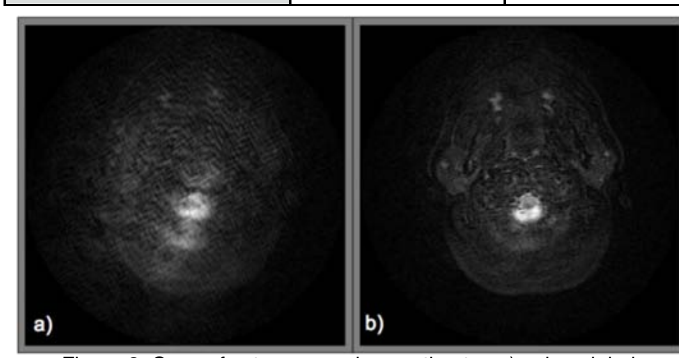

Figure 3: Case of extreme spurious estimates a) using global correlation maxima and b) using local correlation maxima.

REFERENCES: 1. Pipe, Mag. Res. Med. 42(5) 1999, 963-9. 2. Forbes et. al., Mag. Res. Imag. 14(3) 2001, 215-22.

ACKNOWLEDGEMENTS: Funded in part by GE Healthcare