

# Noise Correction on Rician Distributed Data for Fiber Orientation Estimators

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## Introduction

Several groups have proposed reconstruction techniques, including Q-Ball imaging [2], PASMRI [3] and spherical deconvolution [1,4,5] methods, based on the DW signal profile, that resolve the multiple fiber populations without prior knowledge of the number of fibers within the voxel. The metric used by these methods is based on the root mean square error but the Rician statistics, which comes from the magnitude reconstruction of the MR data, introduces a deviation on the signal profile that is not taken into account. However, these strategies have demonstrated a high degree of robustness that allows us to raise a signal profile correction in the common case of a single signal for each spatial direction, either coming from a single or from the average of magnitude reconstructed signals. We propose the Maximum-Likelihood (ML) solution [6] of the magnitude-reconstructed signal of each spatial direction, in order to take into account the artifacts of the Rician statistics and to improve the fiber orientation estimations. This transformation keeps the fiber orientations and increases the sharpness of the final profile.

## Methods

**Theory:** When the Number of Signal Averages (NSA) is set to 1, the magnitude reconstructed signal follows the Rician distribution ( $R$ ) that introduces a blurring on the DW signal profile [6]. It can be demonstrated that the estimated fiber orientations are not spatially modified by the Rician distribution because of the monotonic increasing relationship between the noisy,  $M$ , and the unnoisy MR signal,  $A$ . On the other hand, the monotonic decreasing relationship between the ratio  $M/A$  and  $A/\sigma$  implies a loss of sharpness on the fiber orientation shape. When  $NSA > 1$ , the distribution is not Rician anymore and it tends to be Gaussian when  $NSA \rightarrow \infty$ . We can demonstrate that the new distribution is obtained through  $NSA-1$  weighted convolutions of the Rician distribution:  $p_{NSA}(M; A, \sigma) = NSA \cdot (\otimes_{NSA-1} R)(M \cdot NSA; A, \sigma)$ , where  $\sigma$  is the standard deviation of the complex MR data and  $\otimes_{NSA-1}$  indicates the NSA-1 convolutions. However, the new expectation is still given by the Rician expectation and therefore the blurring on the signal is still present. For each NSA, a single normalised correction curve can be obtained as the ML solution, given by:  $A_{ML}(M, NSA) = \arg\{\max_A [p_{NSA}(M; A, \sigma)]\}$ . In figure 1 the relationship between the normalised ML,  $A_{ML}/\sigma$ , and the normalised measurement,  $M/\sigma$ , is shown for NSA equal to 1, 2, 3, 5 and  $\infty$ . The transformation imposes a threshold as a minimum signal acceptable. **Simulations:** Signal of 2 fibers crossing at  $60^\circ$ , tensor [1.7, 0.3, 0.3] (10-3mm<sup>2</sup>/s), b-value 3000 s/mm<sup>2</sup>, complex gaussian noise with  $SNR(T_2) = 10$  and  $NSA = 3$  were performed. Data were sampled under 92 directions, interpolated to 1082 directions and 100 trials were run. **In vivo data:** DTI-EPI data of a normal human brain were acquired through 92 directions, with b-value  $\approx 3000$  s/mm<sup>2</sup>,  $NSA = 3$ , and an estimated  $SNR(T_2) \approx 12$ . The correction scheme has been applied to the simulated and in-vivo data for each spatial direction. Two deconvolution methods [1,4] have been used for the fiber orientation estimation.

## Results

In figure 2, results of the simulations on the uncorrected and corrected data are represented as the mean profile (green) and the mean plus standard deviation profile (gray) over the 100 trials. On the top the Richardson-Lucy (R-L) [1] and on bottom the Maximum Entropy (ME) [4] deconvolution results are shown. The red lines represent the true fiber orientations. The generalized fractional anisotropy (GFA) [2] of the fiber orientation distribution is also indicated as an index of sharpness. Figure 3 shows the in-vivo results, interpolated to 1082 directions, of the R-L deconvolution before (right) and after (left) the signal profile correction. For visual purposes, some voxels have been squared in red. In order to compare the uncorrected and corrected results in simulations and in-vivo data, the deconvolution parameters were kept within each deconvolution approach.

## Conclusions

The signal noise correction presented imposes a threshold as a minimum signal acceptable, and keeps the fiber orientations increasing the sharpness of the final estimations. An improvement on the fiber orientation distribution is always found when signal correction was applied. Due to the robustness of the deconvolution algorithms, the correction scheme permits to counteract the noise artifacts with a negligible computational cost.

## References

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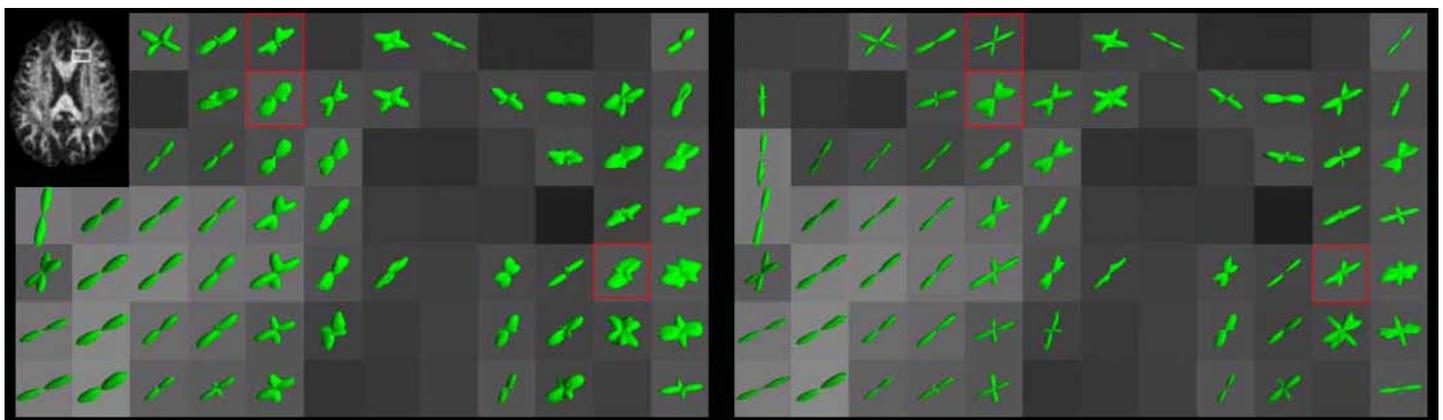
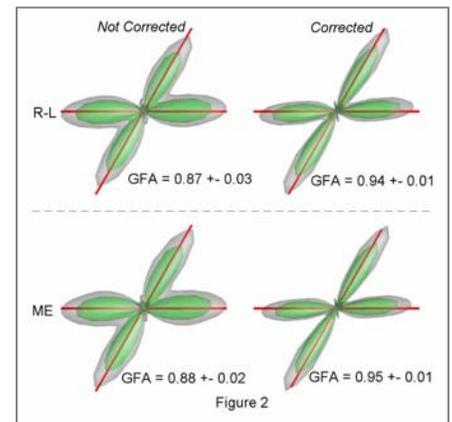
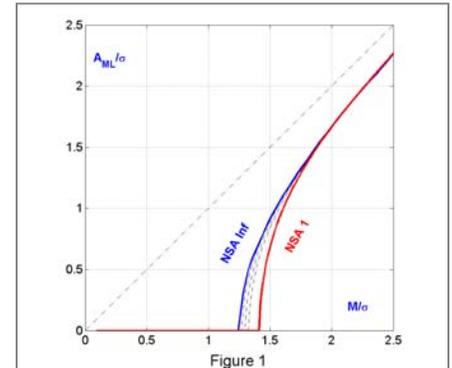


Figure 3