# Artificial Phantoms for Studies of Anisotropic Diffusion in the Brain

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## Introduction

Diffusion Tensor Imaging (DTI) provides access to fibre pathways and structural integrity in white matter and is an expanding area of the research. It finds important clinical applications in managing neurodegenerative diseases such as Alzheimer's disease or multiple sclerosis. Many advanced techniques have been recently suggested for the reconstruction of the diffusion orientation distribution function with an enhanced angular resolution (HARDI). In order to enable better access to the sensitivity of the proposed diffusion indices to the underlying microstructure, it is important to develop artificial model systems that exhibit the required properties, on the one hand, but benefit from a reduced complexity on the other. The aim of this work is to construct simple phantoms that are characteristic of a sufficiently strong anisotropy and are suitable for a validation of the analytical models.

## Phantom construction and results

"Parallel-" and the "cross-" fibre phantoms were constructed using hydrophobic polyethylene fibres (Dyneema® DTX 70, courtesy of DSM, Netherlands) and acrylic glass supports as shown in Fig. 1. Fibre type was selected based on the literature [1, 2] and the relaxation properties of water in contact with fibres. Fibres were wound around a support and pressed between two additional plates. Air bubbles were removed using a vacuum pump. The Apparent Diffusion Coefficients (ADC) and the transverse relaxation times ($T_2$) were measured on a 3T Siemens MAGNETOM Trio scanner using pulse sequences provided by manufacturer (double spin-echo EPI sequence and multiple-slice multiple-echo spin-echo sequence, CPMG-type). Figure 1 shows maps of the ADC, $T_2$, and fractional anisotropy (FA).

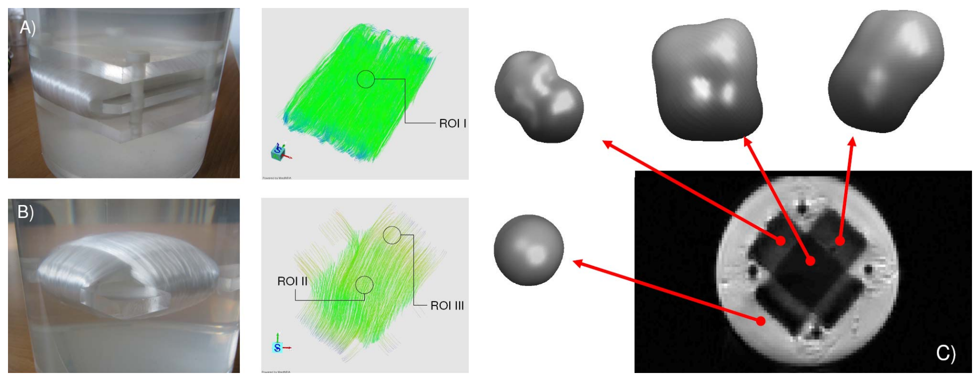


*Figure 1. Photographs and DTI-based fibre tracks of the parallel- (A) and the cross- (B) fibre phantoms. ADC profile approximations (C) reconstructed on the basis of tesseral harmonics [3] overlaid on the $T_2$ map.*

In the fibre areas, diffusion appears to be strongly anisotropic. Whereas the diffusivity along the fibres in the parallel fibre regions (ROI I and ROI III) was rather close to that of the bulk water ($\approx 2.3\times10^{-3}$ mm$^2$s$^{-1}$), diffusion across the fibres was considerably reduced (up to a factor of 4). The diffusion anisotropy was strongly influenced by the fibre density. The values of FA in the densely packed "parallel" phantom reached 0.6-0.7 (ROI I) relevant for the ordered white matter structures. In the cross-fibre area, all diffusion tensor eigenvalues appeared reduced in comparison to the parallel-fibre regions as a result of the restrictions imposed by the fibres in both the parallel and perpendicular directions.

The fibre orientation of the "parallel" phantom could be tracked reasonably using the algorithm based on the DTI (free software package MedINRIA), Fig. 1. However, in the cross-fibre area, the tracking algorithm has failed due to the limitations of the DTI-based algorithms. In contrast, the ADC profiles reconstructed using tesseral harmonic decomposition of the HARDI signal illustrate different fibre orientations in the crossing and parallel regions, Fig. 1c.

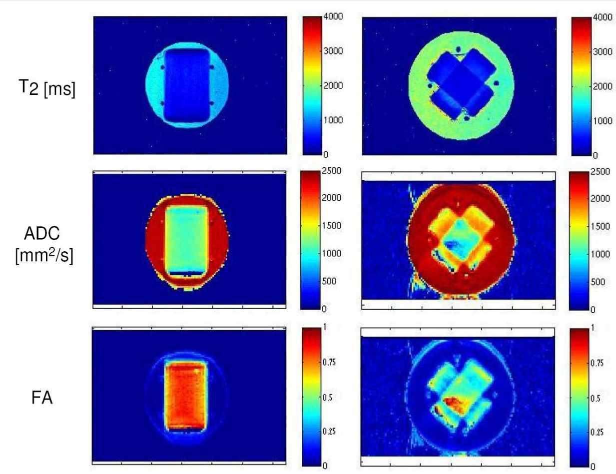


*Figure 2. The maps of $T_2$, ADC and FA.*

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## References

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