# Analysis of tractography biases introduced by anisotropic voxels

Peter F. Neher[1], Bram Stieltjes[2], Ivo Wolf[3], Hans-Peter Meinzer[1], and Klaus H. Fritzsche[1,2]
[1]*Medical and Biological Informatics, German Cancer Research Center (DKFZ), Heidelberg, Germany,* [2]*Quantitative Image-based Disease Characterization, German Cancer Research Center (DKFZ), Heidelberg, Germany,* [3]*Medical Informatics, Mannheim University, Mannheim, Germany*

**Purpose:** MR diffusion imaging-based tractography noninvasively provides insight into the course of white matter pathways in the living human brain and adds important information used e.g. for surgery planning. In research it is common practice to acquire DWI data with an isotropic resolution. In contrast, clinical and especially intraoperative datasets are often acquired with a relatively high in-plane resolution of about 1-2 mm but much thicker slices (2-5 mm)[1,2,3]. The impact of anisotropic voxels on the outcome of different tractography approaches has not been systematically analyzed yet, even though tractography is widely used in clinical settings. This work uses software phantom data to quantify the impact of anisotropic voxels on nine different publicly available and commonly used algorithms. Further, two effects are differentiated: (1) algorithmic biases that can be corrected by resampling of the datasets and (2) irreversible effects that must be considered in future when implementing clinical image acquisition schemes.

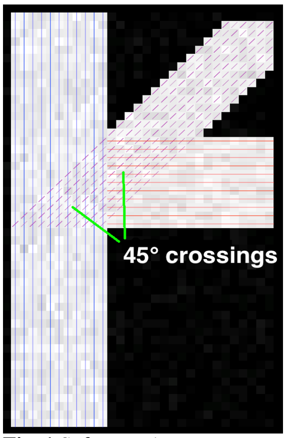

**Fig. 1** Software phantom

**Methods:** Synthetic DWI datasets were generated using a linear combination of tensor based prototype signals. We generated a structure similar to the branching of the corticospinal tract spreading into the motor cortex which is a highly critical location e.g. during tumour resection. The phantom consists of a vertical main strand and two lateral strands branching in a 45° and 90° angle as depicted in Fig. 1. Three datasets were generated, simulating a b-value of 1000 s/mm$^2$, 30 gradient directions and an SNR of 15, which would be a realistic intra operative setup. The first image was generated with an isotropic resolution of 1.25 mm. The second and third image were generated with an increased resolution along the z-axis of 2.5 and 5 mm respectively. Vice versa, the anisotropic images were upsampled to an isotropic resolution, thus allowing the comparison of tractography on the natively isotropic image vs. tractography on the merely upsampled isotropic ones and thereby enabling the evaluation of the effects (1) and (2) mentioned above. We selected 9 commonly used tractography algorithms ranging from simple tensor streamlining over probabilistic methods and more sophisticated modeling techniques to global approaches (Tab. 1). Selection of parameters like an FA threshold was not an important issue due to the fact that the algorithms were only compared to themselves and that all algorithms yielded satisfying results using default parametrization. We evaluated the change in the amount of fibers tracked between the seed ROI and ROI 1 to 3 respectively at different anisotropy levels (Fig. 2).

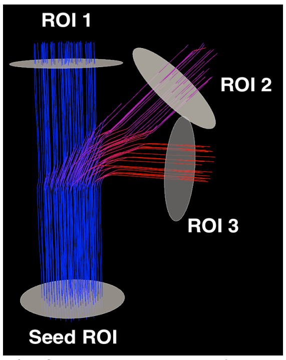

**Fig. 2** Seed and target regions

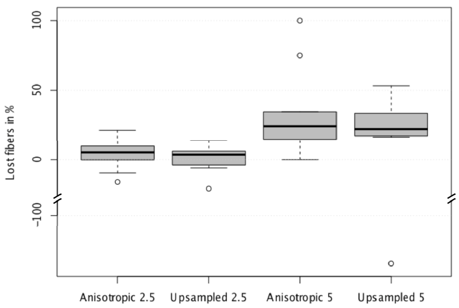

**Fig. 3** Percentage of fibers lost for ROI 1.

**Results:** The results were quite different for the three target ROIs. The percentage of fibers reaching ROI 1 showed little or no reaction to the first degree of anisotropy but in the 5 mm slice thickness case a distinct decrease of the fiber number was observed (Fig. 3). The most striking and for all algorithms consistent effect was observed in the percentage of fibers reaching ROI 2 (Fig. 4). Almost all algorithms yielded less fibers reaching this ROI with increasing anisotropy of the image resolution. The effect could be somewhat reduced by upsampling the image to the isotropic resolution. ROI 3 also showed strong effects but they did not yield a common trend for all algorithms (Fig. 5).

| | |
|---|---|
| **1** | Tensorlines |
| **2** | DTI FACT |
| **3** | DTI Streamline |
| **4** | CSD Deterministic |
| **5** | CSD Probabilistic |
| **6** | Unsc. Kalman Filter |
| **7** | Gibbs Tracking |
| **8** | PAS Streamline |
| **9** | Probabilistic Streamline |

**Tab. 1** Tractography algorithms

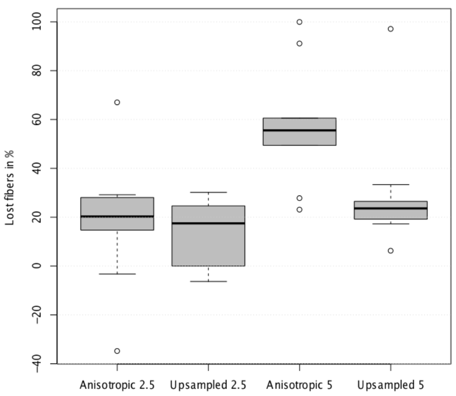

**Fig. 4** Percentage of fibers lost for ROI 2.

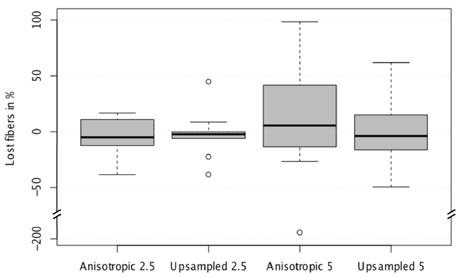

**Fig. 5** Percentage of fibers lost for ROI 3.

**Discussion and Conclusion:** We analyzed the effects of anisotropic voxels, as they are commonly used in clinical settings, on fiber tractography. We could show that highly anisotropic voxels have a strong effect on the capability of the algorithms to deal with a branching situation as modeled in our synthetic dataset and that the effect is amplified with increasing anisotropy. Our results show a distinctly decreased number of fibers reaching the lateral and superior parts of the anisotropic images. We could show that the effect can be reduced, although not eliminated, by upsampling the images to an isotropic resolution. These findings clearly demonstrate that anisotropic voxels are suboptimal for fiber tractography in our setting and indicate that upsampling to an isotropic resolution is in general recommendable. Regarding the widespread use of acquisition protocols with anisotropic image resolution, especially in surgery planning, it seems to be an important concern to verify the findings for other fiber configurations as well as on in-vivo datasets.

**References:** [1] C. Giussani *et al.*, NeuroImage 2010, 52:217–223 [2] M. Skorpil *et al.*, Magnetic Resonance Imaging 2011, 29:289–292 [3] F. Wang *et al.*, Neurol Sci 2011, 2:865–874