$E(3) \times SO(3)$-Equivariant Networks for Spherical Deconvolution in Diffusion MRI

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Abstract

We present RT-ESD, an E(3)xSO(3) equivariant framework for sparse deconvolution of volumetric data where each voxel contains a spherical signal. Such 6D data naturally arises in diffusion MRI (dMRI), a medical imaging modality widely used to measure microstructure and structural connectivity. As each dMRI voxel is typically a mixture of various overlapping structures, there is a need for blind deconvolution to recover crossing anatomical structures such as white matter tracts. Existing dMRI work takes either an iterative or deep learning approach to sparse spherical deconvolution, yet it typically does not account for relationships between neighboring measurements. This work constructs equivariant deep learning layers which respect to symmetries of spatial rotations, reflections, and translations, alongside the symmetries of voxelwise spherical rotations. As a result, RT-ESD recovers underlying anatomy with better accuracy and spatial coherency on several challenge datasets (with known ground truth) and on real-world human brain dMRI. These gains yield improved downstream performance in relevant tasks such as fiber tractography.

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