White Matter Clustering using Conformal Mapping

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PURPOSE

Diffusion Tensor Imaging (DTI) facilitates the delineation of white matter fiber tracts in the brain. Clustering white matter fiber bundles by various methods has been a research focus over the past decade. We propose a deep neural network which requires a novel approach to data normalization, augmentation, and problem formulation.

METHODS

Conformal mapping is a technique used to establish a bijective mapping of one shape into its topologically equivalent target shape; the bijectivity ensures that the mapping is invertible and unique. We used volumetric transformations in which not only the surface of the shape is reshaped into the target shape but every point inside the shape is also transformed. Eleven epilepsy patients without structural brain abnormalities were retrospectively reviewed. Diffusion-weighted imaging was obtained with a multiband spin-echo echo planar imaging sequence on a 3 Tesla MR system (Siemens Vida or Prisma) using a 64-channel head and neck coil.

A total of 64 diffusion directions were obtained. Diffusion data were preprocessed, and orientation distribution function was estimated. Whole brain tractography was then created using deterministic tracking. Fiber tracts from the 11 patients are mixed forming the dataset comprising 2469292 fiber tracts. The dataset was divided into training, test, and validation sets in a 3:1:1 ratio. The neural network classifier is based on the VGG16 architecture and contains two convolution layers with 32 and 64 feature maps followed by two fully connected dense layers. The network uses rectified linear units as the activation function. Fiber tracts with length less than 30 mm or greater than 300 mm are filtered out, and all the fiber tracts are resampled to contain50 points, flipped in order, and convolved with a 1D Gaussian filter for data augmentation. The fiber tracts are then mapped into a spherical space using the conformal mapping. The neural network is trained with a batch size of 500 fibers, a learning rate of 0.0001, and categorical cross-entropy is minimized using Adam optimizer in 10 epochs.

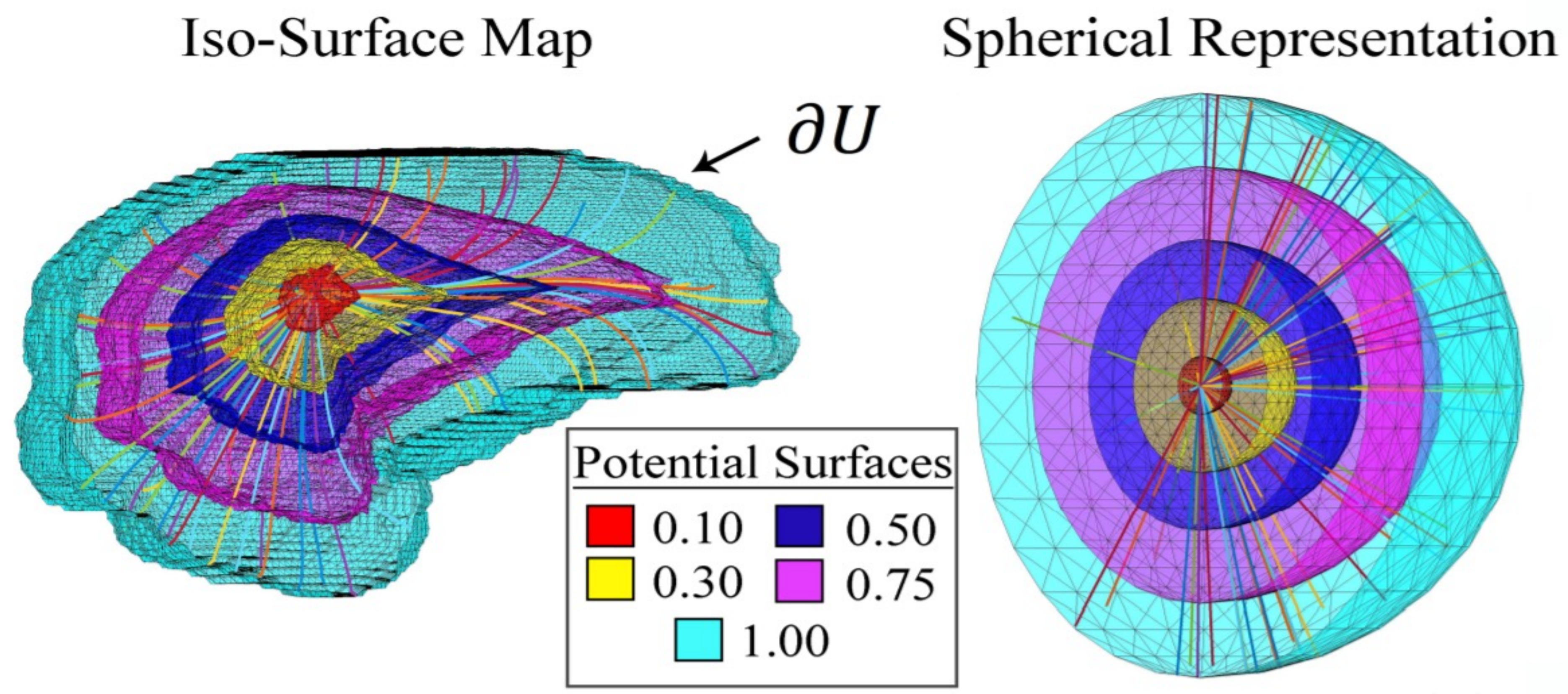

FIGURE: Results of Conformal Mapping. (Left) Shows the streamlines originating from the surface and reaching the center intersecting the equipotential surface orthogonally. (Right) After conformal mapping the streamlines have become radii intersecting the equipotential surfaces (spheres).

RESULTS

All accuracies for 26 tracts exceeded 0.890379.

CONCLUSIONS

We presented a deep learning framework for clustering white matter fibers using a volumetric conformal mapping approach and the initial experiments showed promising results. We aim to automate this process and further this algorithm such that the deep learning tools can eliminate all the noisy fibers and identify the appropriate anatomical clusters based on whole brain tractography. We also aim to expand this algorithm to identify white matter tracts in the presence of pathologies that can change the anatomy of the tracts