Deep Learning Prediction of Left Ventricular Fiber Orientation Using a Ventricular Coordinate System

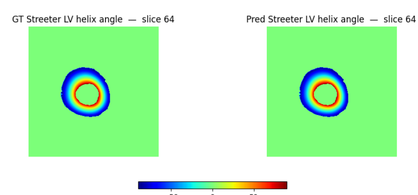
Adrien Junior Tchuem Tchuente*, Jairo Rodríguez-Padilla, Nicolas Cedilnik, Julie Magat, Valery Ozenne, Hubert Cochet, Mihaela Pop, Maxime Sermesant
Centre Inria d'Université Côte d'Azur, Sophia Antipolis, France

Aims: Cardiac fiber orientation is a critical input for electromechanical simulations, as it directly governs electrical propagation and myocardial contraction. Although cardiac diffusion tensor imaging (cDTI) provides accurate fiber orientation, it is time consuming and not used at the patient-specific level in clinical practice. Rule-based methods such as the one proposed by Streeter offer a practical alternative, yet they can be computationally expensive and need additional user input to generate the fiber orientation. This work aimed to develop a deep learning model that replicates the Streeter rule for helix angle (HA) estimation in the left ventricle (LV).

Methods: The LV geometry was represented in the ventricular coordinate system introduced by Cedilnik et al., mapping each point to a normalized (φ, ρ, θ) space encoding circumferential angle, transmural depth, and longitudinal position. The LV wall mask and the corresponding HA maps, computed with the Streeter rule, were projected into this space. A 3D U-Net was trained to predict the HA at each voxel from the LV mask alone. Predictions were subsequently mapped back to Cartesian coordinates via an inverse transform. The model was trained and evaluated on a dataset comprising 8 ovine and 8 porcine hearts, split into training, validation, and test sets.

Results: On the held-out test set, the model achieved a mean squared error (MSE) loss of 0.001 with respect to the Streeter reference HA.

Conclusion: The proposed approach accurately replicates rule-based fiber orientation assignment while significantly reducing computation time. Working in a topology-agnostic coordinate space enables consistent predictions across subjects and species. This method offers a promising step toward fast, personalized fiber orientation estimation for patient-specific cardiac simulations.



Ground truth (left) and predicted (right) HA maps for a representative LV short-axis slice. Colour scale in degrees.