CorticalFlow: A Diffeomorphic Mesh Deformation Module for Cortical Surface Reconstruction

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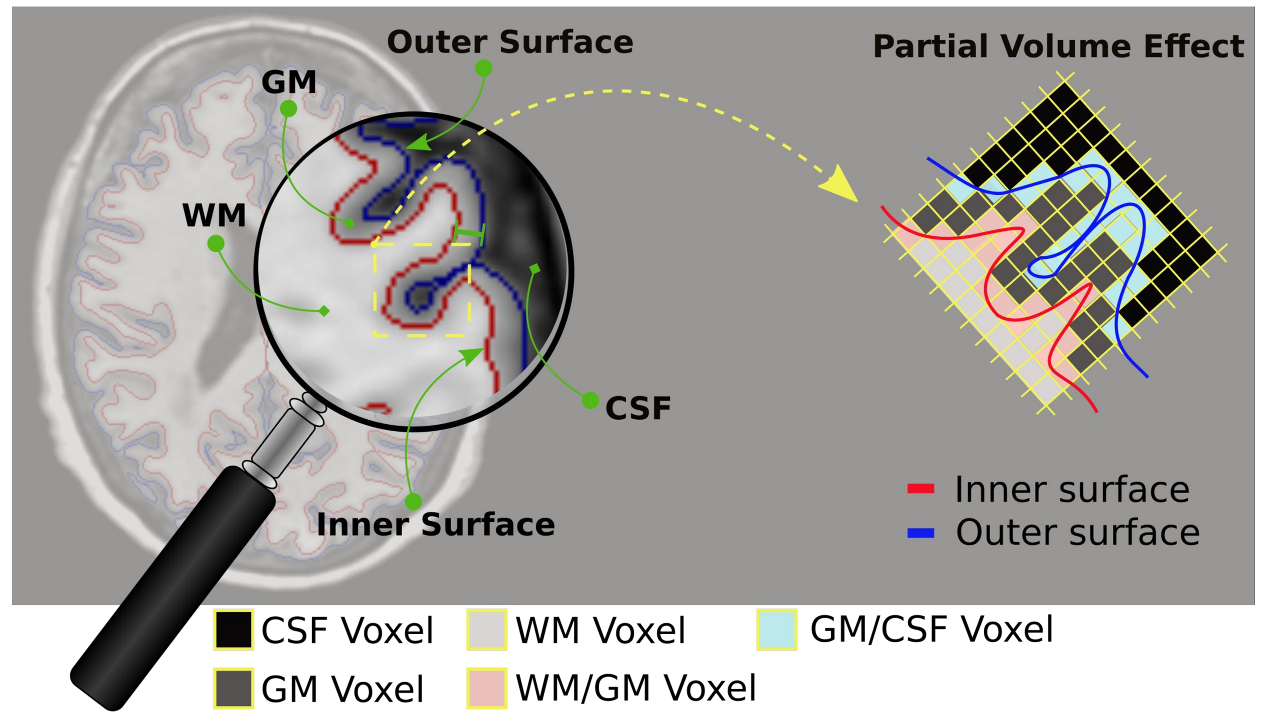
We propose a new geometric deep-learning model that, given a 3-dimensional image, deforms a template mesh with desired properties like topology, connectedness, and resolution to smoothly approximate the geometry of the depicted object while keeping these mesh properties intact.

1) Cortical Surface Reconstruction from MRI (CSR):



Diffeomorphic Mesh Deformation (DMD)

Tractable framework for computing a diffeomorphic mapping Φ for each surface mesh vertex by solving the **flow ODE**,

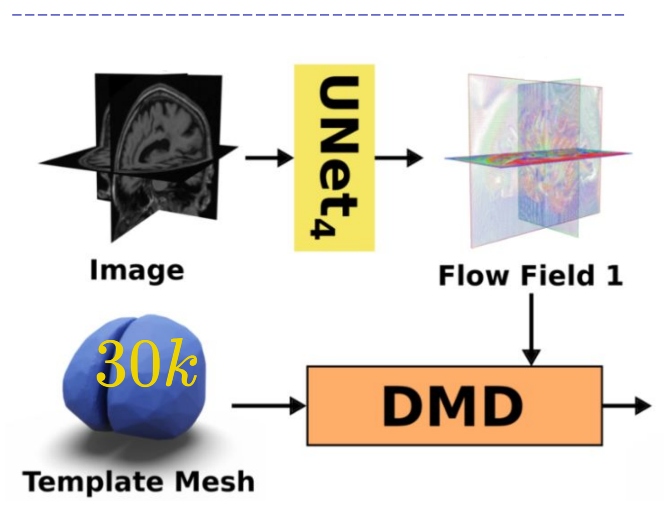
$$\frac{d\Phi(s;\mathbf{x})}{ds} = v\left(\Phi(s;\mathbf{x})\right), \text{with } \Phi(0;\mathbf{x}) = \mathbf{x}$$

using the iterative approximation method,

$$V^i_{k+1} = V^i_k + hv(V^i_k), \text{with } h = \frac{1}{N}$$

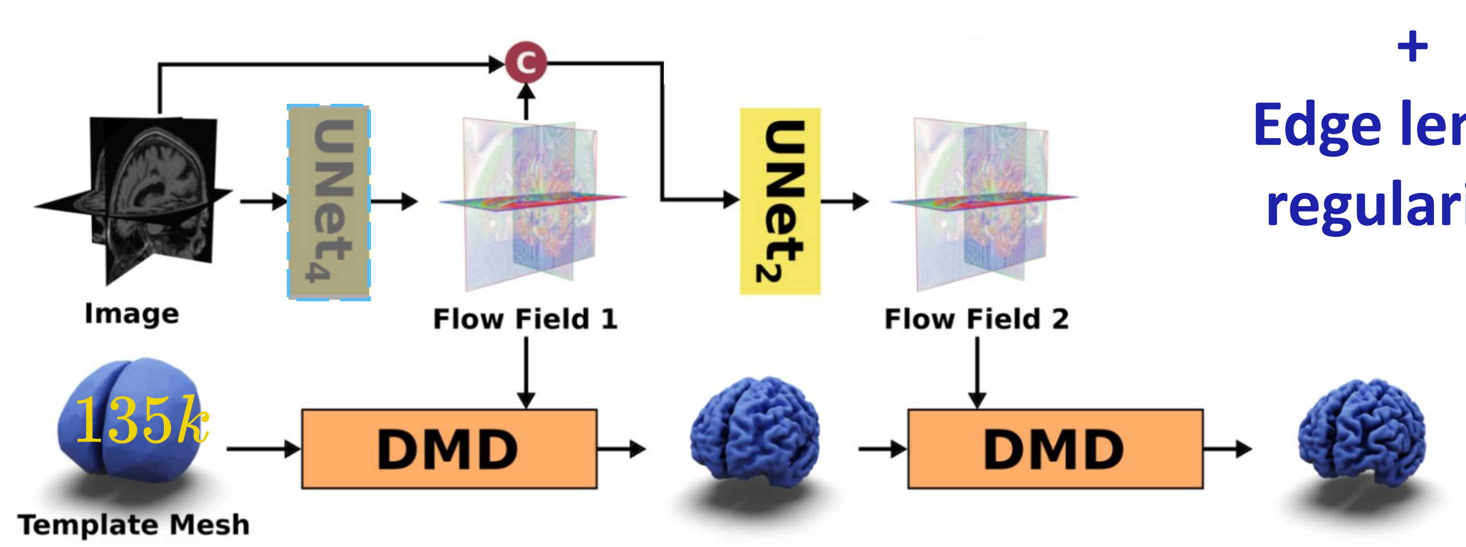
provided by the forward Euler method.

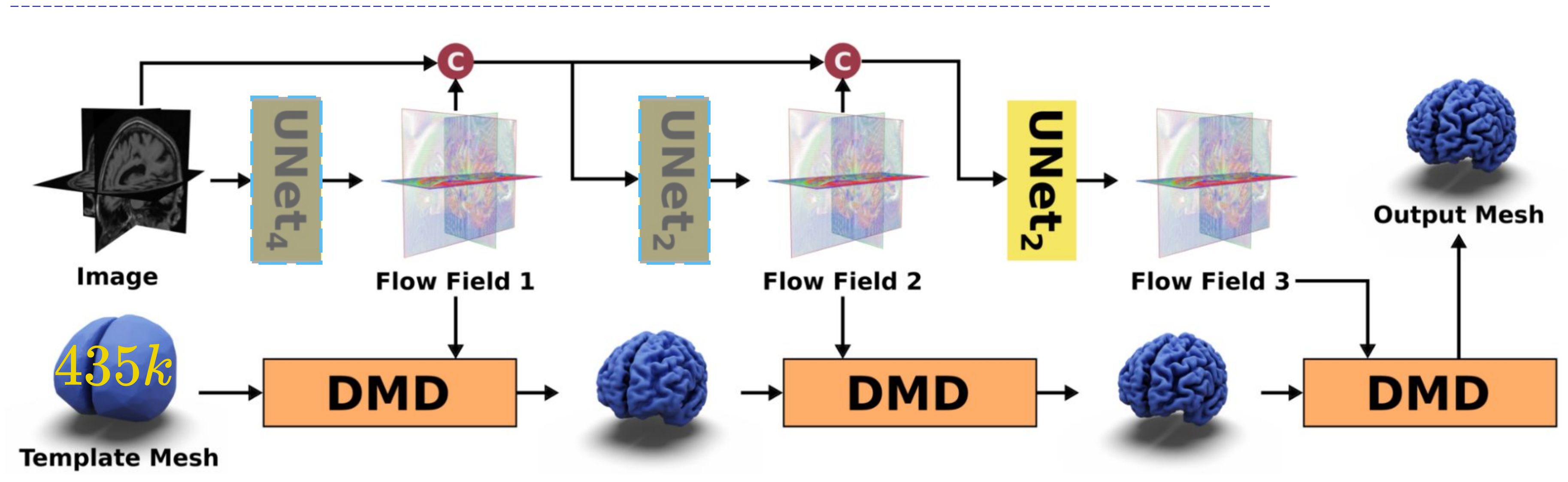
2) CorticalFlow Model and Training Procedure:



$$\underset{\theta_i}{\operatorname{argmin}} \sum_{(I,S)\in\mathcal{D}} \mathcal{L}\left(CF^i_{\theta_i}(I,\mathcal{T}_i), S\right)$$

Chamfer Distance + Edge length regularizer

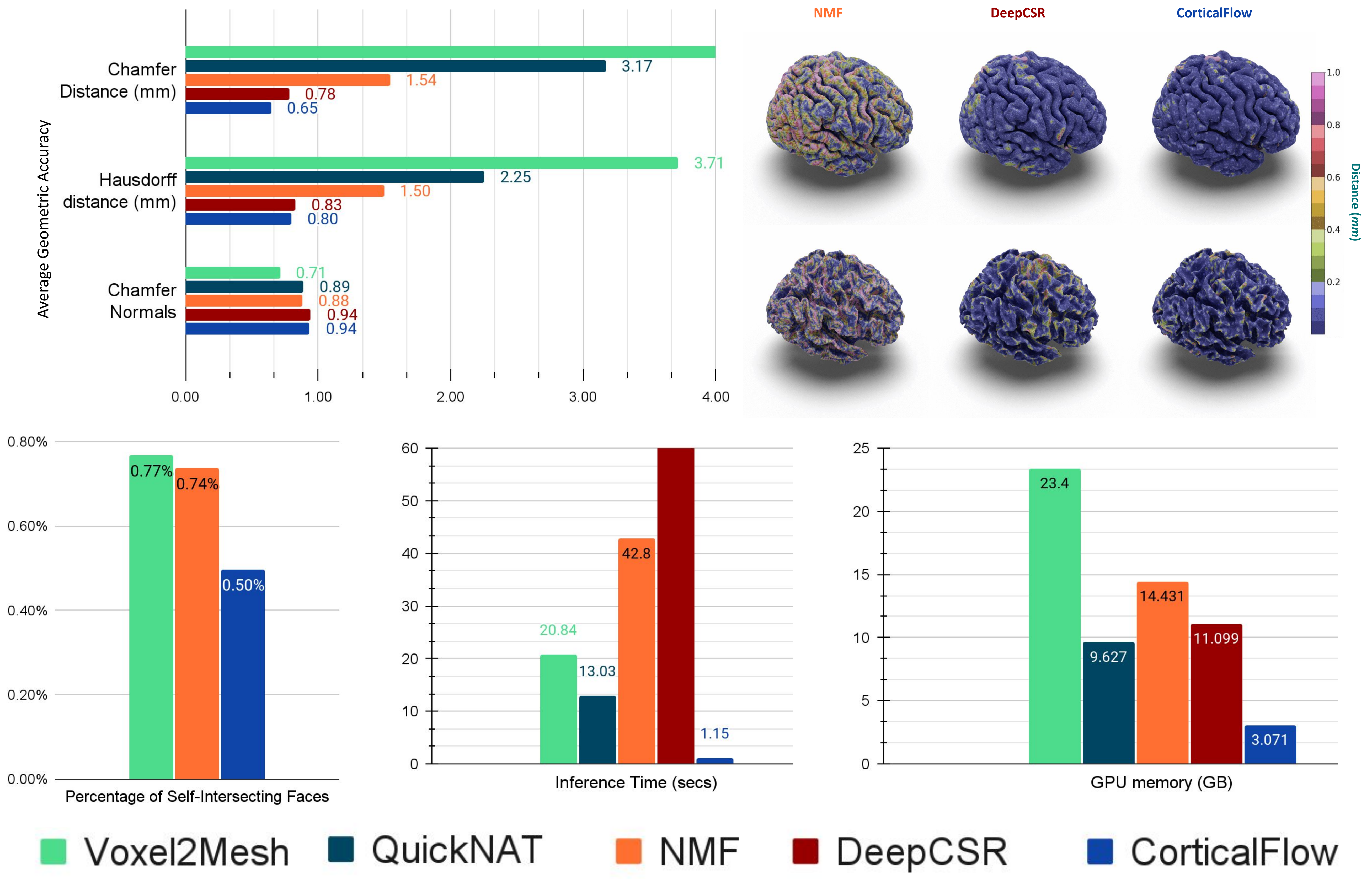




$$\mathrm{CF}^1_{\theta_1}(\mathbf{I},\mathcal{T}_1) = \mathrm{DMD}\left(\mathrm{UNet}^1_{\theta_1}(\mathbf{I}),\mathcal{T}_1\right)$$

$$\mathrm{CF}^{i+1}_{\theta_{i+1}}(\mathbf{I},\mathcal{T}_{i+1}) = \mathrm{DMD}\left(\mathrm{UNet}^{i+1}_{\theta_{i+1}}(\mathbf{U}_1^\frown \cdots \mathbf{U}_i^\frown \mathbf{I}), \mathrm{CF}^i_{\theta_i}(\mathbf{I},\mathcal{T}_{i+1})\right)$$

3) CSR Benchmark:



https://lebrat.github.io/CorticalFlow/

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