The tools described above are now used to estimate a smooth fiber organization from 3D ex-vivo DT-MRI data. For the ROUKF we use the a priori values \( \Theta_\ast = 60° \), \( \text{std}_0 = 10.0 \), \( \gamma = 1.0 \), and 144 degrees of freedom for the surface angles distribution, on a 1.7M tetrahedra mesh.

We propose to estimate rule-based myocardial fiber model (RBM) parameters from DT-MRI, with the goal of personalizing the fiber architecture for cardiac simulations. The RBM is based on a space-dependent angle distribution on the heart surface and then extended to the whole domain through an harmonic lifting of the fiber vectors. For the angles estimation we use a static Unscented Kalman Filter (UKF). We also show the effect of different fiber distributions on cardiac contraction simulations.

**Rule-based fiber model**

The construction of the spatially variant fiber model includes the following parts:

- Lifting operation (L) of surface parameter \( g(x) \):
  \( \Delta f(x) = 0 \), for \( x \in \Omega \)
  \( f(x) = g(x) \), for \( x \in \Gamma \cap \partial \Omega \)
  \( \partial_h f = 0 \), for \( x \in \partial \Omega \)

- Construction of axial and circumferential coordinate system

- Bilinear interpolation of \( \Theta \) in axial and circumferential direction

- Rule-base fiber algorithm, inspired from [1]: For given long-axis evaluate:
  I. For surface \( \pi \) do:
    For every node \( x_j \in \pi \) do:
    1. Evaluate the local pseudonormal \( n(x_j) \), circumferential direction \( c(x_j) = \text{cross}(n(x_j), l) \) with \( \lambda(x_j) = \{+1, \text{for } x_j \in \text{spacium} \}
       \{-1, \text{for } x_j \in \text{spacium} \} \)
    2. Compute the interpolation of angle \( \Theta(x) \)
    3. Generate the surface fibers:

II. Solve the harmonic lifting (L) with \( g(x) \)

**Unscented Kalman Filter**

We aim to minimize the following functional:

\[
J(\Theta) = ||f_m - f(\Theta)||^2_{W^{-1}} + ||\Theta - \Theta_\ast||^2_{P^{-1}}
\]

with:

- noisy fiber measurements \( f_m \) from DTMRI measurements
- rule-base algorithm \( f \) with variables \( \Theta \)
- a priori estimate \( \Theta_\ast = \gamma \text{Id} \), \( P = (\text{std}_0)^2 \text{Id} \), \( \gamma \), \( \text{std}_0 \) positive scalars
- norms \( || \cdot ||_W \) and \( || \cdot ||_P \) for weighting the terms

For solving this least squared problem for \( \Theta \) we apply the reduced order unscented Kalman filter (ROUKF) [2] in a static manner:

- simplex sigma points, recursively calculated via
- Innovation for each particle:

\[
\frac{1}{\sqrt{\text{det}(P)}} \left[ \begin{array}{c} u_{i+1}^j \\ \vdots \\ u_{i+k}^j \end{array} \right]
\]

- Estimation

\[
\hat{\Theta} = \gamma \Theta_\ast - \text{L}_P \left( \text{U} \right) \text{W}^{-1} \text{L}_T 
\]

\[
\delta_{\Theta_{\text{Cor}}} = \Theta - \text{L}_P \left( \text{U} \right) \text{W}^{-1} \text{L}_T
\]

\[
P_{\Theta_{\text{Cor}}} = \text{L}_P \text{U} \left( \text{L}_P \right)^T
\]

**Results**

The tools described above are now used to estimate a smooth fiber organization from 3D ex-vivo DT-MRI data. For the ROUKF we use the a priori values \( \Theta_\ast = 60° \), \( \text{std}_0 = 10.0 \), \( \gamma = 1.0 \), and 144 degrees of freedom for the surface angles distribution, on a 1.7M tetrahedra mesh.

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DTMRI data Openly available on [http://gforge.icm.jhu.edu/gf/project/dtmri data sets](http://gforge.icm.jhu.edu/gf/project/dtmri data sets); **Geometry created from in-vivo CT – imaging (courtesy of Klinikum Rechts der Isar)**