NURBS-based isogeometric analysis of a bi-ventricular heart model

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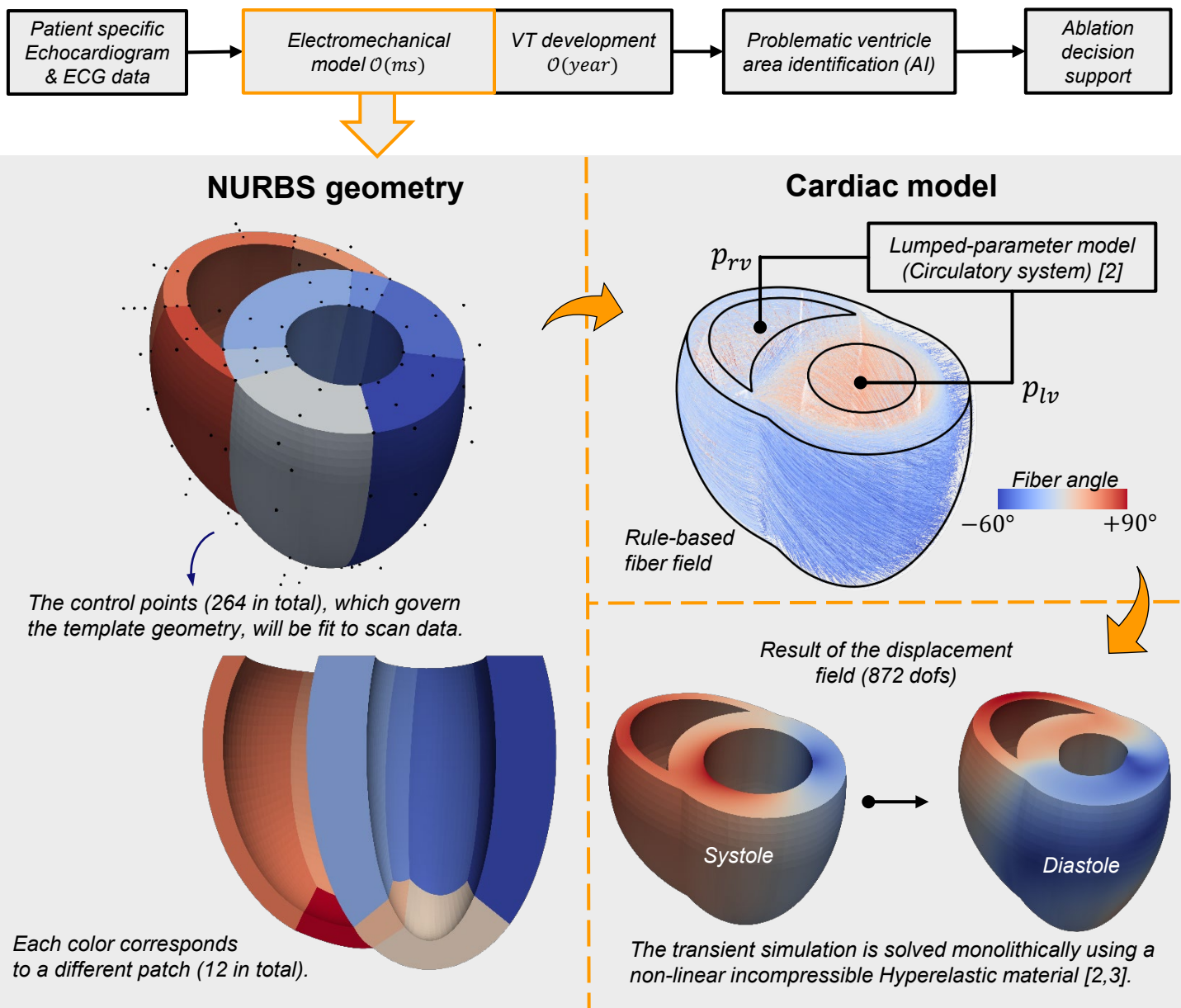R. Willems[1,*], C.V. Verhoosel[1], O. van der Sluis[2,3]

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Motivation and objective

Computer simulations provide information that can be used by clinicians to support decision-making regarding the treatment of Ventricular Tachycardias (VTs). It is the goal of this project to develop efficient and robust models that can be integrated into the clinical workflow.

Simulation workflow

Our simulation framework combines the Isogeometric Analysis (IGA) simulation paradigm [1] with image recognition techniques to obtain patient-specific computer models. Simulations will be performed directly on a Non-Uniform Rational B-Spline (NURBS) bi-ventricular geometry.

Patient specific Echocardiogram & ECG data → Electromechanical model $\mathcal{O}(ms)$ → VT development $\mathcal{O}(year)$ → Problematic ventricle area identification (AI) → Ablation decision support

NURBS geometry

The control points (264 in total), which govern the template geometry, will be fit to scan data.

Each color corresponds to a different patch (12 in total).

Cardiac model

p_{rv}

Lumped-parameter model (Circulatory system) [2]

p_{lv}

Fiber angle
$-60°$ $+90°$

Rule-based fiber field

Result of the displacement field (872 dofs)

Systole   Diastole

The transient simulation is solved monolithically using a non-linear incompressible Hyperelastic material [2,3].

Project outlook

IGA has the potential to give robust geometry and analysis models in the considered scenario of limited input data. Future project steps focus on the automation of image-based geometry reconstruction, while extending the model validation and clinical-integration. Attention will be given towards parameter sensitivity and uncertainty quantification.

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