Automated Cardiac Constitutive Modelling: Deriving Strain Energy Functions with Evolutionary Regression

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Introduction: Cardiac diseases are frequently associated with irregularities in the elastic properties of cardiac tissue. However, current strain energy functions describing these properties have been manually designed for specific experimental setups. Therefore, they may not be optimal in terms of simplicity or generalizability to novel experiments. In contrast, we present CHESRA (Cardiac Hyperelastic Evolutionary Symbolic Regression Algorithm), a new approach for automatically deriving strain energy functions directly from experimental data.

Methods: In CHESRA, we used a customized genetic algorithm to evolve simple symbolic representations of hyperelastic strain energy functions. The fitness of each function was quantified by how well it fit to experimental data with an additional penalty for function complexity. The data under consideration consisted of six different cardiac triaxial shear and biaxial stretch experiments.

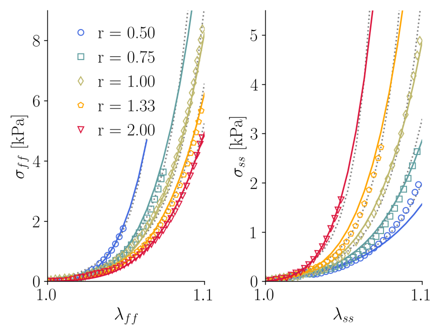

Fig. 1: Model fit for a biaxial stretch experiment. Markers: Stress (σ) versus tissue extension (λ) in the fibre (f) and cross-fibre (s) direction for varying stretch ratios (r) assessed by Sommer et al. in human left ventricular myocardium; Solid lines: Fit of the CHESRA model; Dotted lines: Fit of the Holzapfel-Ogden model.

Results: The resulting strain energy functions were algebraically simpler than the state-of-the-art Holzapfel-Ogden model, while providing accurate fits to all datasets (example in Fig. 1).

Conclusion: CHESRA automatically derives simple and generalizable strain energy functions directly from experimental data. Thus, CHESRA may be employed for future investigations of cardiac mechanics and contribute to the development of personalized and effective treatments for heart diseases.