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INVERSE PROBLEMS IN BIO-FLUIDS AND -SOLIDS

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MINI-SYMPOSIUM PROPOSAL

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1 BACKGROUND

Hybrid experimental--computational characterization of soft tissues as well as personalization of computational biomechanics models of organs require the solution of inverse problems, i.e. to estimate properties of the model (constitutive parameters of the tissue, boundary conditions, and/or initial conditions) from partial measurements of the system. The mathematical formulation of these problems – and therefore its numerical solution strategy -- depends on the type and amount of measured data and the underlying biophysical model. This Minisymposium aims to gather together researchers from different mathematical and application areas in biomechanics to share their recent developments. Recently a series of symposia were organized on these topics including successful mini-symposia at CMBE 2017 Pittsburgh and at CMBE 2019 Sendai.

2 MOTIVATION

It has become a common practice to combine image based full-field displacement measurements experienced by tissue samples in vitro, with custom inverse methods to infer (using nonlinear regression) the best-fit material parameters and the rupture stresses and strains [5]. Similar approaches also exist for characterizing the material parameters of soft tissues in vivo, where advanced medical imaging can provide precise measurements of tissue deformation under different modes of action, and inverse methodologies are used to derive material properties from those data [3]. Nowadays, these approaches offer important possibilities for fundamental mechanobiology which aims at gaining better insight in the growth, remodeling and ageing effects in biological tissues [2]. It is well-known that biological soft tissues appear to develop, grow, remodel, and adapt so as to maintain particular mechanical metrics (e.g., stress) near target values. To accomplish this, tissues often develop regionally varying stiffness, strength and anisotropy. Important challenges in

soft tissue mechanics are now to develop and implement hybrid experimental - computational method to quantify regional variations in properties in situ.

In biofluids, e.g. blood flows, the personalization of the models is a key step which relies on inverse problems using clinical data, namely medical images for measuring both anatomy and function of the vasculature. In the modeling community, the development of methods for incorporating data into models has grow rapidly in the last years most likely due to the increased availability of such data in clinical centers and the growing interest of modelers and clinicians in closer collaborations. Key examples are the estimation of boundary conditions in the fluid [8], including reduced order representations [10] and compensation of geometrical inaccuracies [7] in pure fluid dynamics simulations; but ultimately including the coupling with the solid [6] and its boundary conditions [9].

The main motivation of the symposium is to review the latest progress and permit scientific discussions on these methods by bringing together researchers interested by those inverse problems from experimental as well as clinical data both for bio-solids and bio-fluids.

3 FOCUS OF THE MINI-SYMPOSYUM

Topics to be considered are related to the different challenges posed by inverse problems in soft tissue biomechanics and mechanobiology, such as:

- in vivo identification of parameters using medical imaging
- model fitting against uncertain experimental results
- optimization approaches and model order reduction
- regularization approaches
- uncertainty assessment in inverse problems
- inverse problems from full-field measurements in solids and fluids
- machine-learning and data-driven discovery in material characterization
- hyperelastic image registration.

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