INVERSE SIMULATION FOR RETRIEVING THE UNDEFORMED POSITION FOR HYPERELASTIC MATERIALS : APPLICATION TO BREAST SIMULATIONS

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Key Words: *Inverse deformation, finite element method, medical simulations.*

The rest position, as well as any associated internal stresses in soft organs, are usually unknown when solving biomechanics problems. In addition, the initial geometry of a specific organ, obtained from medical images, is affected by external forces. An example is breast MRI performed prior to cancer surgery. During the imaging routine, the breast is elongated in prone position in order to better view the tumor. However, during surgery, the patient is in supine position, which causes the breast to rest in a completely different state. To simulate this state from the prone stance, the rest configuration is needed as well as the pre-stress mapping of the organs [1].

To tackle this problem, iterative algorithms have been proposed such as Sellier's method [2]. In this fixed-point approach, the rest configuration is updated by multiple forward calculations then repeated until the error (between the updated and target configuration) reaches an established threshold. The method presents many benefits e.g. easy implementation and fast convergence. However, convergence issues appear at large deformations induced for instance by hyperelastic material formulations.

In this work, we develop a simple formulation and a robust solution procedure for inverse deformation problems in soft-tissue biomechanics using the FEniCS Project finite element solver. In contrast with iterative algorithms, our method can solve with a single simulation the rest position without computing multiple solutions of the forward problem. For a fixed convergence tolerance, our physics-based algorithm is about ten times faster and better handles large deformations than Sellier's method [2]. Moreover, no additional direct deformation simulations from the rest configuration are required to compute stresses in the organ. The framework is implemented within an open-source pipeline enabling the seamless, fully parallelized, direct and inverse deformation simulation of organs directly

from segmented images. The pipeline is also designed to be flexible to user's needs: for example, it allows the modification of the constitutive models by changing a single line of code.

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FUNDING