Accepted Manuscript

An augmented iterative method for identifying a stress-free reference configuration in image-based biomechanical modeling

Manuel K. Rausch, Martin Genet, Jay D. Humphrey

PII: S0021-9290(17)30222-1
DOI: http://dx.doi.org/10.1016/j.jbiomech.2017.04.021
Reference: BM 8202

To appear in: *Journal of Biomechanics*

Received Date: 23 December 2016
Accepted Date: 24 April 2017

Please cite this article as: M.K. Rausch, M. Genet, J.D. Humphrey, An augmented iterative method for identifying a stress-free reference configuration in image-based biomechanical modeling, *Journal of Biomechanics* (2017), doi: http://dx.doi.org/10.1016/j.jbiomech.2017.04.021

An augmented iterative method for identifying a stress-free reference configuration in image-based biomechanical modeling

Manuel K. Rausch[a,b,*], Martin Genet[c,d], Jay D. Humphrey[a]

[a]*Department of Biomedical Engineering, Yale University*
[b]*Department of Aerospace Engineering & Engineering Mechanics, University of Texas at Austin*
[c]*LMS, École Polytechnique, CNRS, Université Paris-Saclay*
[d]*Inria, Université Paris-Saclay*

Abstract

Continued advances in computational power and methods have enabled image-based biomechanical modeling to become an important tool in basic science, diagnostic and therapeutic medicine, and medical device design. One of the many challenges of this approach, however, is identification of a stress-free reference configuration based on in vivo images of loaded and often prestrained or residually stressed soft tissues and organs. Fortunately, iterative methods have been proposed to solve this inverse problem, among them Sellier's method. This method is particularly appealing because it is easy to implement, convergences reasonably fast, and can be coupled to nearly any finite element package. By means of several practical examples, however, we demonstrate that in its original formulation Sellier's method is not optimally fast and may not converge for problems with large deformations. Fortunately, we can also show that a simple, inexpensive augmentation of Sellier's method based on Aitken's delta-squared process can not only ensure convergence but also significantly accelerate the method.

Keywords: Inverse Methods, Fixed-Point Methods, Aitken's Delta-Squared Process, Stress-free Reference Configuration, Image-Based Biomechanical Modeling

1. Introduction

Image-based biomechanical modeling has become an important tool in basic science, diagnostic and therapeutic medicine, and medical device design (Baillargeon et al., 2015; Rausch et al., 2016a; Bosmans et al., 2016). Ever improving image resolution and computational power increasingly enable models with greater detail. One key challenge remains, however. Tissues and organs, in vivo, are often prestrained and residually stressed in addition to experiencing time-varying in vivo loads (Han and Fung, 1991; Bellini et al., 2014; Tepole et al., 2016). Thus, the stress-free reference configuration is, in general, not readily accessible from in vivo images (Weisbecker et al., 2014).

*Corresponding author
Email address: manuel.rausch@utexas.edu (Manuel K. Rausch)