11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20–25, 2014, Barcelona, Spain

REAL-TIME NUMERICAL SIMULATION OF SOFT TISSUES

S. Niroomandi[1], D. Gonzalez[1], I. Alfaro*[1] and E. Cueto[1]

[1] Aragon Institute of Engineering Research (I3A). Universidad de Zaragoza.
{siamakn,gonzal,iciar,ecueto}@unizar.es

Key words: *Real time, model order reduction, proper generalized decomposition (PGD), asymptotic numerical method (ANM).*

Surgical simulators are used to train students and surgeons before working with patients. One of the difficulties in creating this kind of simulators is modelling the complex behaviour of human tissues, very often modelled as (possibly visco-) hyperelastic media, and solving the resulting system of equations in real time: 1kHz of feedback response if we think of haptic devices, or 25 Hz if we need for visual feedback only.

Currently, very few surgical training simulators at this level incorporate accurate models for tissue deformation. Some of these are based on the use of explicit finite elements implemented on hardware (Graphic Processing Units, GPU). Recently, a growing interest has been paid to investigate Model Order Reduction (MOR) techniques in this framework, such as Proper Orthogonal Decomposition (POD) or Proper Generalized Decomposition (PGD).

Proper Generalized Decomposition is a priori model order reduction technique in which the essential field is approximated as a finite sum of separable functions. PGD is an efficient technique to solve not only high dimensional problems but also parametric problems, considering parameters as new dimensions of the state space of the model.

In this work we explore the possibilities of PGD methods applied to real time simulation of hyperelastic solids. It will be shown how a multi-dimensional formulation of the problem, in which the displacement is expressed as to be dependent on both the physical coordinates and the position and orientation of the applied loads, opens the door to simulations with feedback rates on the order of one kHz. The developed strategy comprises an off-line computation strategy, in which a high-dimensional problem is solved. This solution provides in fact a sort of meta-model or computational vademecum that can be stored in a very compact form. Then, an on-line simulation strategy is developed that solves the meta-model at impressive feedback rates.

An hyperelastic material is used to model material behavour. In order to solve the non linear system of equations PGD is combined with Asymptotic Numerical Method (ANM) for a consistent linearization of the weak form of the problem. ANM is based upon expanding some variables of the problem in the neighborhood of each material point in terms of a control parameter, prior to their introduction in the weak form of the problem. This approach leads to a sequence of linear problems which can be solved by PGD.