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MODEL ORDER REDUCTION METHODS FOR COMPUTATIONAL SURGERY

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Traditionally, surgeons have been trained to perform minimally invasive surgery with the help of animal or mechanical models. Nowadays computational mechanics, however, offer a unique opportunity to substitute these techniques by more sophisticated surgical simulators with haptic (force) feedback.

The main difficulties of such an approach come from the fact that (i) soft tissues are strongly non-linear (usually modelled as hyperelastic), undergoing large displacements and strains and (ii) an accurate haptic feedback response must be provided at rates on the order of 1kHz. This means that we must be able to solve large strain, non-linear problems one thousand times per second. For realistic applications this still constitutes a challenge.

Most approaches developed so far can be grouped into the category of supercomputing, since they employ a sort of “brute force” approach to the problem (explicit dynamics in massively parallel architectures such as GPUs, for instance).

Our work constitutes a different an innovative approach to the problem, in which a strategy based on model order reduction has been envisaged. Thus, models are constructed with as few degrees of freedom as possible, by employing judiciously chosen sets of basis functions. This is what is commonly known as the Proper Orthogonal Decomposition (POD) approach to the problem. The main drawback of such a technique is the need for solving several full-order models in order to extract from their results relevant information to construct the basis.

On the contrary, a technique developed by the authors, among others, and coined as Proper Generalized Decomposition (PGD) allows for an a priori construction (off-line) of these basis, and their subsequent employ on-line under severe real-time constraints.

In this talk we will review aspects related to the efficient evaluation of non-linear (hyperelastic) models of soft tissues, about the real-time simulation of their dynamics and give some insight about the simulation of surgical cutting in real time.

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