NUMERICAL DETERMINATION OF AN ANATOMICAL STRUCTURE'S UNLOADED STATE FROM IN VIVO MEDICAL IMAGING

Nathan Collin (1,2), Bertrand Watrisse (1) , Simon Le Floc'h (1), Dominique Ambard (2), Julien Sigüenza (2)

1. Laboratoire de Mécanique et Génie Civil (LMGC), Montpellier, France; 2. Sim&Cure, Montpellier, France

Introduction

Medical imaging allows to bio-mechanician to obtain in vivo geometrical data, useful for patient-specific organic tissues mechanical modeling. However, geometrical data coming from medical imaging describe a strained state of anatomical structure under anatomical loading (such as weight, pressure, arterial tension etc). The non-linear mechanical behavior of the soft tissues constituting those structures prevents to easily find their unloaded geometry.
One who wants to study intravascular device positioning through mechanical computation would need a method to determine the unloaded state of an anatomical structure, assuming its mechanical behavior and its boundary conditions.
Numerical methods exist to find the unloaded geometry of a given loaded one, supposing the boundary conditions. Along those methods, some need from the user to write the variational formulation thus to have a control on the used solver [1]. Other methods can use enough of a structural solver as a black box [2], [3].
Most of those methods use volumic finite element modelling. Our work targets on applying such methods to shell and beam element and present limitations.

Methods

The fixed point algorithms found in the literature have been modified to work with shell or beam modeling, as presented in Figure 1. In particular, rotations must be taken into account.

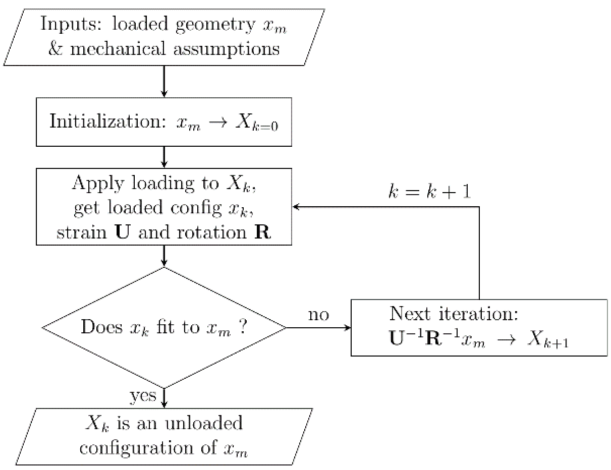

Figure 1: Proposed algorithm for the backward displacement method strategy applied to shell or beam modeling.

Results

This algorithm was applied to simple cases and to anatomical ones. A case of cerebral aneurysm obtained from 3D rotational angiography is presented in Figure 2. It is supposed under homogeneous inner pressure, with nodes from its outlet totally blocked and hyperelastic mechanical behavior from literature [4].

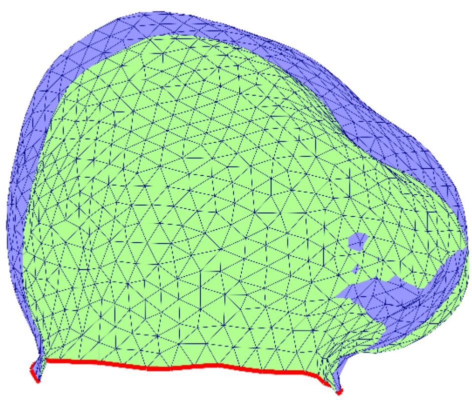

Figure 2: Cut view of a cerebral aneurysm with outlet in red, geometry from medical imaging in blue and unloaded geometry in green.

Discussion

With the presented algorithm, we successfully approximated the solution of the inverse elastostatic problem of an anatomical structure's inflation, through shell modeling.
We found that in addition to its dependence on material modeling and image analysis accuracy, this method is highly dependent on boundary conditions. Wrong agreement between those parameters would result in mechanical incompatibilities and prevent the algorithm to converge.
In particular, contact between the aneurysm wall and bone structures can lead to divergence of the algorithm. Our work allows us to better identify and detect these cases of non-convergence.

References

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