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PARALLEL SIMULATIONS OF SOFT-TISSUE USING AN ADAPTIVE QUADTREE/OCTREE IMPLICIT BOUNDARY FINITE ELEMENT METHOD

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Octree (3D) and quadtree (2D) representations of computational geometry are particularly well suited to modelling domains that are defined implicitly, such as those generated by image segmentation algorithms applied to medical scans [5].

In this work we consider the simulation of soft-tissue which can be modelled with a incompressible hyperelastic constitutive law. We include the effects of both non-linear geometry and material properties in our model.

Similarly to Moumnassi et al. [2] we use the implicitly defined level set functions as the basis for a partition of unity enrichment to more accurately represent the domain boundary on the cartesian quadtree/octree mesh. In addition we introduce arbitrary cuts and discontinuities in the domain using ideas from the classical extended finite element method [3].

Because of its hydrated nature soft-tissue is nearly incompressible [1]. We explore the use of a classical two-field displacement-pressure (u-p) mixed approach to deal with the problem of volumetric-locking in the incompressible limit [4].

We exploit the existing parallel capabilities available in the open-souce finite element toolkit deal.ii [6], including the advanced mesh partitioning and balancing recently introduced in the p4est library [7]. The resulting method scales to run over hundreds of cores on the University of Luxembourg HPC platform.

REFERENCES

[1] V. Libertiaux, F. Pascon, and S. Cescotto. Experimental verification of brain tissue incompressibility using digital image correlation. *J. Mech. Behav. Biomed. Mater.* doi:10.1016/j.jmbbm.2011.03.028, 2011.

[2] M. Moumnassi, S. Belouettar, É. Béchet, S. P. A. Bordas, D. Quoirin, and M. Potier-Ferry. Finite Element Analysis on Implicitly Defined Domains: An Accurate Representation Based on Arbitrary Parametric Surfaces. *Computer Methods in Applied Mechanics and Engineering*, doi:10.1016/j.cma.2010.10.002, 2010.

[3] L. Jerabkova and T. Kuhlen. Stable Cutting of Deformable Objects in Virtual Environments using XFEM. *IEEE Computer Graphics and Applications*, doi:10.1109/MCG.2009.32, 2009.

[4] G. Legrain, N. Moës, and A. Huerta. Stability of Incompressible Formulations Enriched with X-FEM. *Computer Methods in Applied Mechanics and Engineering*, doi:10.1016/j.cma.2007.08.032, 2007.

[5] A. Eklund, P. Dufort, D. Forsberg, and S. M. LaConte. Medical Image Processing on the GPU – Past, Present and Future. *Medical Image Analysis* doi:10.1016/j.media.2013.05.008, 2013.

[6] W. Bangerth, R. Hartmann, and G. Kanschat. Deal.II—A General-purpose Object-oriented Finite Element Library. *ACM Trans. Math. Softw.* doi:10.1145/1268776.1268779, 2007.

[7] C. Burstedde, L. C. Wilcox, and O. Ghattas. P4est: Scalable Algorithms for Parallel Adaptive Mesh Refinement on Forests of Octrees. *SIAM Journal on Scientific Computing* doi:10.1137/100791634, 2011.