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A FIXED-GRID FINITE ELEMENT METHOD FOR MOVING INTERFACES APPLIED TO THE DEVELOPMENT OF BIOLOGICAL TISSUES

Thomas Rüberg*,[1] and José Manuel García Aznar[2]

[1]Fundación ARAID, Zaragoza, Spain, thru@unizar.es
[2]Universidad de Zaragoza, Zaragoza, Spain, jmgaraz@unizar

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The development of biological tissues is an example from a vast field of applications in mechanobiology where material interfaces move in space and time. The quantitative analysis of the dynamics of the material discontinuity is crucial to understand the overall biological process. The large deformation of the composition of materials with nonlinear behaviour is intractable by analytic approaches and computational analysis is a promising tool to gain more insight to the phenomena.

We present a novel Finite Element Method which operates on a fixed background grid that is not affected by the material motion (for a similar approach, see [1] for fluid flow applications and [2] for the analysis of fluid-structure interaction problems). Boundary and interface conditions are incorporated weakly in a variationally consistent manner. Since the behaviour of the considered materials can be fluid- or solid-like, the derivation is based on balance laws in an Updated Lagrangian formalism and independent of the material. By backtracking the particle motion, convective terms are avoided and all internal variables are available throughout the simulation process. The location of the interface is represented implicitly by a level set technique and updated with the displacement increments.

A particular application of the new method is the continuum mechanical modelling of the migration of an individual cell [3]. Cell migration is of fundamental importance in tissue development, but can also have a detrimental role as in metastasis. The presented simulation technique allows to employ complex material behaviours for the cell body and its environment, precisely capturing the dynamics of the material interfaces. Different models of cell locomotion are tested in different environments and assessed by means of current experimental findings.

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