Simulation Organogenesis in Comsol: Deforming and Interacting Domains

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Abstract

Organogenesis is a tightly regulated process that has been studied experimentally for decades. We are developing mechanistic models for the morphogenesis of limbs, lungs, and kidneys with a view to integrate available knowledge and to better understand the underlying regulatory logic. In our previous paper on simulating organogenesis in Comsol (German et al Comsol Conf Procedings 2011) we discussed methods to efficiently solve such models, predominantly on a static domain. Organ size, however, changes dramatically during development, and tissues are composed of several layers that may expand both together or independently. Moreover, the developmental processes are typically embedded in an environment, and diffusional exchange with this environment can affect the patterning process. Simulations during which large deformations of the domain take place often are not stable with Comsol default solver settings and are too slow to permit efficient screening of the parameter space for biologically realistic solutions. Here we discuss methods to build and efficiently solve models in Comsol:
- that are defined on a composite domain comprising of several sub-domains;
- that involve implicitly defined deformations of simple and composite domains;
- that involve explicitly defined deformations of composite domains;
The proposed models for morphogenesis are formulated as sets of partial differential equations on deforming and interacting domains. We implement our models in Comsol combining PDE and ALE interfaces. The size of the discretized models is typically in the range from 50 000 to 500 000 degrees of freedom or higher.