A computational framework for anisotropic growth

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The simulation of biomaterials became an active research topic during the past two decades. Especially the consideration of the symmetry group of the underlying material has attracted several research groups.

In this context, our contribution aims at the development of a phenomenological and computational framework for anisotropic growth within a finite element setting. We consider in particular the simulation of soft tissues and skeletal muscles which are commonly characterized by representative fibers. It is thereby well–known that the fiber diameter increase or even decrease depending on the applied load level.

For the proposed computational framework, it is basically the concept of structural tensors that serves as a convenient framework to incorporate transversal isotropy, i.e. a single rank one structural tensor determined by a fiber vector is introduced. It is obvious, that this structural tensor acts as an internal variable and consequently enters the free energy function. To be specific, we model three different adaption effects which allow to be activated separately:

First, the balance of mass accounts for an additional source term which also influences the balance of linear momentum, energy and entropy. The corresponding evolution equation for the referential density takes a well–established energy–driven format.

Second, we set up an evolution equation for the fiber diameter or rather the norm of the structural tensor, respectively. Once more an energy driven format is chosen that allows to account of diameter in– and decrease.

Finally, in view of the evolution of the fiber orientation we adopt the idea that the potential energy takes a minimum if the axes of anisotropy coincide with the principal stain and therefore stress directions. The angular velocity vector of the fiber orientation is therefore determined by the cross product of the fiber itself and the principal direction which is correlated to the maximal strain (or alternatively stress) eigenvalue.