Multi-Scale Computational Mechanics for Skeletal Muscles

Sheng-Wei Chi

Civil & Environmental Engineering Department,
University of California, Los Angeles (UCLA), Los Angeles, CA 90095, USA
email: chishengwei@ucla.edu

Modeling biological tissues remains one of the most challenging tasks in computational mechanics due to the nature of live materials, where their behavior is closely related to the change of environment. Moreover, the architecture of heterogeneous complexity adds additional obstacle to the modeling of biological systems where tremendous efforts are devoted to CAD geometry construction and Finite Element mesh generation.

In this work, we model the passive behavior of muscle tissues as a transversely isotropic hyperelastic material and model the active behavior of muscle fiber with a phenomenological law and a micro-structural kinetics law. We introduce a computational method that takes the pixels of medical images directly as the discretization points in the simulation model without the need of mesh generation. This computation is formulated based on meshfree methods, such as the Reproducing Kernel Particle Method and the Radial Basis Collocation Method, for solving PDE in conjunction with the level set method and segmentation algorithms to automatically identify boundaries and material interfaces in the simulation model that contains only the image pixels. A variational level set method based on the Chan-Vese segmentation functional is employed to segment a stack of medical images and identify the boundary of a 3D object accordingly. This approach has been applied to the simulation of the soleus muscle and the numerical results have been verified through magnetic resonance imaging (MRI) experiments.