Modelling the neuromuscular system

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Abstract

Skeletal muscles consist of parallel-aligned muscle fibers, in which thousands of basic contractile units, i.e. the sarcomeres, are arranged in series. Upon stimulation, an electrical signal (action potential) propagates along the length of the muscle fibers and induces via complex signaling pathways the interaction of the myofilaments in the underlying sarcomeres.

The centrepiece of the presented neuromuscular model is a multi-scale and multi-physics chemo-electro-mechanical skeletal muscle model. This model is based on biophysical principles follows a bottom-up approach, cf. [3, 6]. On the micro-scale, a detailed biophysical cell model is solved describing the entire excitation-contraction pathway in a sarcomere. On the meso-scale, the propagation of action potentials along muscle fibers is described. The contractile stresses determined on the micro-scale are homogenized and included in a transversely isotropic continuum-mechanical constitutive equation describing the overall mechanical behavior of skeletal muscle tissue on the macro-scale.

Implementing all the entire pathway from motoneuron activation to skeletal muscle force generation is implemented within the open-source software framework OpenCMISS [1]. Such models include several unique physiological properties such as, for example, force enhancement [2], and novel homogenisation techniques. In particular the homogenisation techniques are designed to provide a framework for deriving subject-specific (passive) skeletal muscle tissue constitutive laws based on the volume fraction and distribution of the collagen fibres, which surround the fibres. As far as extending the single muscle models to neuromuscular system models, here an activation-driven forward dynamics model of a two-muscles muscular system as introduced in [7], has been developed for investigating the biomechanical behaviour of musculoskeletal systems and their control.

Besides the mechanical aspects, the chemo-electromechanical model provides a natural framework for computing surface and intramuscular EMG data [4, 5] providing a tremendous source for validating neuromuscular skeletal muscl models. The talk will provide an overview on how we can use mathematical and engineering-like approaches to gain a deeper insight into the human body.

References

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