Three-Dimensional Continuum-Mechanical Modelling of the Musculoskeletal System

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Abstract

Most musculoskeletal system models appeal to multi-body simulation frameworks, in which the skeletal muscle force generation is modelled using Hill-type skeletal muscle models. Such modelling frameworks have the advantage that they can analyze and predict movement using musculoskeletal system models with a realistic number of muscle (groups). However, these multi-body simulation frameworks are also based on limiting modelling assumptions, e.g., reducing anatomical and physiological complexity to a few lumped parameters. Therefore, they cannot be used to investigate key phenomena like muscle-muscle or muscle-bone interaction. Musculoskeletal system models appealing to three-dimensional, continuum-mechanical skeletal muscle models could naturally overcome such limitations. However, such models are rare, require sophisticated constitutive models, and large computational resources. This is particularly true for forward-dynamics simulations that are based on optimization. Based on the currently only published forward simulations of a two-muscle upper limb model cf. [1, 2], particular challenges in modelling musculoskeletal system models consisting of multiple continuum-mechanical skeletal muscle models will be discussed. For example, while one can extract the geometry and muscle fiber architecture from medical imaging techniques such as MRI or diffusion tensor MRI, extracting functional aspects such as the stress-free configuration from imaging is challenging. Furthermore, the challenge of identifying and selecting appropriate constitutive models and computational aspects to reduce computational cost and to enable forward-dynamics simulations of continuum-mechanical musculoskeletal system models will be also discussed.

References

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[2] J. Valentin, M. Sprenger, D. Pflüger, and O. Röhrle, *Gradient-based optimization with B-splines on sparse grids for solving forward-dynamics simulations of three-dimensional, continuum-mechanical musculoskeletal system models.* IJNMBE, 34(5):e2965, 2018.