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A MUSCULOSKELETAL MODEL OF THE SHOULDER COMBINING MULTIBODY DYNAMICS AND FEM USING B-SPLINE ELEMENTS

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Summary: Research in the biomechanics of motion relies on the use of musculoskeletal models to gather clinical insights. The usual approach is to model a bone as a rigid body, while a muscle consists of lumping its volume in one or several line-segments representing its various lines-of-action. However, due to internal force transfer between fascicles, the size of attachment, and the collisions with its surroundings, a muscle cannot be reduced to the sum of individual lines.

Using the Finite Element Method, one can model the volumetric extent of the muscles, allowing to capture 3D deformations and afford complex collisions between different parts. However, present models are highly detailed, which severely limits the scope of possible studies due to simulation time summing up in hours for a simple motion.

Our goal is to build a musculoskeletal model of the shoulder directed toward clinicians in the context of surgical planning. We evaluated multiple frameworks fulfilling the following technical specifications: proposing a graphical interface, a physics engine solving in a unified manner the finite element method, rigid body mechanics, and contact mechanics.

We present a model of the shoulder allowing us to perform inverse dynamics in minutes. To remain near real-time, we use coarse meshes of the muscles made up of hexahedra elements equipped with linear basis functions. However, a small amount of such elements may not be suitable for models undergoing large deformations such as muscles, e.g. due to shear-locking.

To overcome this limitation, we propose to model muscles using higher-order elements, with B-Spline volumes through an embedded approach, and B-Spline surfaces for muscles which fall under the shell assumption, i.e. thickness much smaller than the other two dimensions. Higher order basis functions are computationally more demanding than linear elements, however, the fewer number of degrees of freedom needed to capture the same deformations modes may be a good tradeoff. We compare the usage of these higher-order elements over line-segments and linear elements in the context of a muscusloskeletal simulation of the shoulder.