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Design, simulation and control of a biomechanical model of the upper limb

O. Zoufalý[a], V. Halamka[b], M. Daniel[a], Z. Šika[b]

[a] *Division of biomechanics, Faculty of Mechanical Engineering, Czech Technical University in Prague, Technická 4, 160 00 Prague, Czech Republic*
[b] *Division of mechanics and mechatronics, Faculty of Mechanical Engineering, Czech Technical University in Prague, Technická 4, 160 00 Prague, Czech Republic*

1. Introduction

Human musculoskeletal modelling is a complex discipline whose results can be applied to both robotics and medicine [4]. In robotics, these models can be used, for example, to design humanoid robots or supportive exoskeletons. In the medical field, these models can be used to investigate various movement limitations such as weakening of a specific muscle group, limited range of motion in joints, etc. The aim of this paper is to develop a comprehensive dynamic model of the upper limb that will become the basis for further research.

2. Musculoskeletal model

The dynamic model of the upper limb was built using Simscape (Matlab). This tool allows the direct application of physical solids and the definition of constraints between them, replacing the creation of differential equations of motion. Simscape also allows the visualization of the solved problem (Fig. 1) and the combination of multibody with electrical or fluid systems.

The skeletal dynamic model is based on the real geometry of the upper limb skeleton (thorax, scapula, clavicle and humerus) [3]. The individual bones were first placed in space and then connected in series using spherical constraints. The model also includes the geometry of

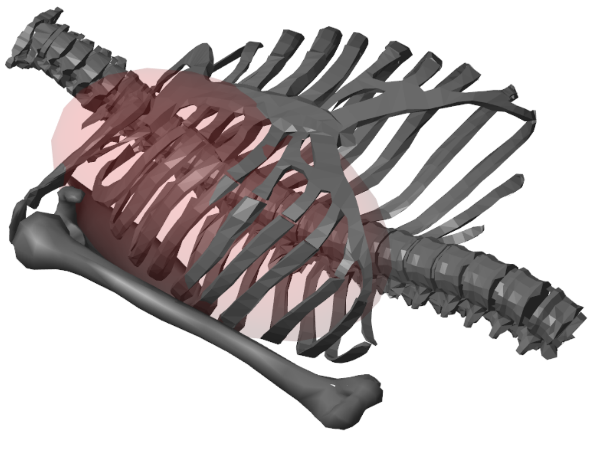

Fig. 1. Simscape visualisation of upper limb skeleton

scapular motion (including scapulohumeral rhythm), which is implemented by using an ellipsoid (Fig. 1) whose geometry approximates the shape of the thorax. The scapula then glides over the surface of this ellipsoid through one to three contact points.

Subsequently, the skeletal model was extended with a muscle model. The Hill and Huxley models are the most commonly used. The Hill model is based only on mechanical interaction and is easier to implement for models with a higher number of muscles. The muscle-tendon complex (Fig. 2) consists of a muscle part (contractile and passive elements) and an elastic tendon. The muscle force is then dependent on the contraction speed and the ratio of current to optimal muscle length. Huxley's model of muscle is slightly more complex and represents muscle contraction in both mechanical and metabolic terms.

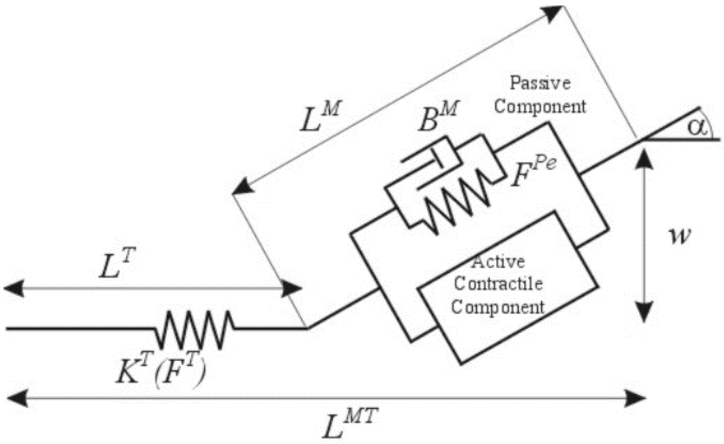

Fig. 2. Hill model scheme [2]

3. Computed muscle control

The Computed Muscle Control method was chosen to control the dynamic model (Fig. 3). This method combines the classical Computed Torque Control method and Static Optimization. In the first step, the desired acceleration of the model is modified using a PD controller based on the control deviation. In the second step, the moments acting at the joints are calculated from this acceleration to achieve the desired trajectory. And in the last step, these moments are converted to forces in each muscle by optimization.

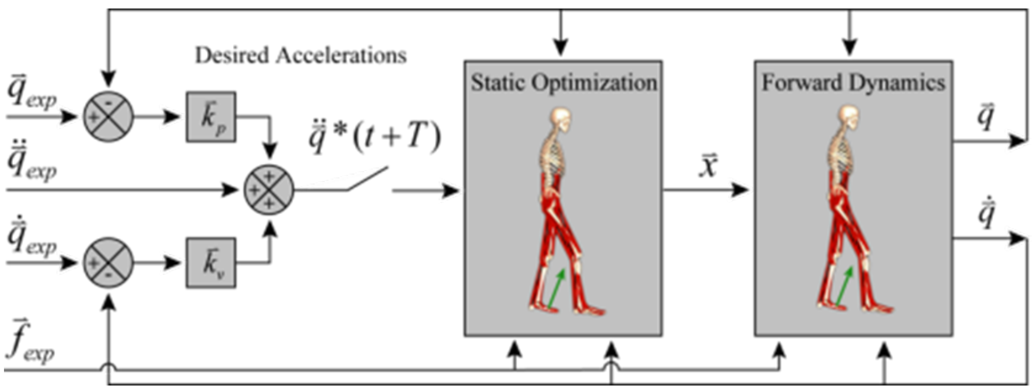

Fig. 3. Computed Muscle Control scheme [1]

Acknowledgements

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