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Development of a personalized musculoskeletal human shoulder model

J. Špička[a], J. Vychytil[a], T. Ryba[b], L. Havelková[a]

[a] New Technologies – Research Centre, Univerzitní 8, 306 14 Plzeň, Czech Republic
[b] Faculty of Applied Sciences, University of West Bohemia, Univerzitní 8, 306 14 Plzeň, Czech Republic

Musculoskeletal disorders of the upper extremity are extremely common and one of the major causes of disability, sickness absence and health care usage worldwide [3]. In fact, musculoskeletal conditions is the most frequent cause of disability severely affecting individuals' daily lives [2]. With an ever growing and aging population, number of diseases typical for elderly people is expected to increase. To address these issues, detailed knowledge of the human body biomechanics is essential.

The aim of this study is to contribute to the development of personalized musculoskeletal human shoulder model for the prevention, therapy and rehabilitation strategies. Namely, we participate in the development of the virtual shoulder model in the AnyBody Modeling System (AMS). This model consists of bones that are interconnected via kinematic joints, muscles with corresponding tendons and ligaments. The bones are considered as rigid bodies. Each muscle with corresponding tendon is represented with several virtual elements in the model that are usually referred to as lines of action. These lines are considered as hill-type models and allows for the active motion of the model as a whole. An important task in the model development is setting realistic muscle paths in order to predict accurate acting forces and moments. To achieve that, artificial obstacles are used in the AMS model to avoid unreal muscle shapes and excessive sliding. Namely, the torus obstacle method is used [1]. It means that for each muscle line, tori obstacles are defined. The path is then given as a shortest connection of muscle attachments, closely wrapping the torus surface. Hence, the key issue of the model development is to define proper position and radii of each torus obstacle. These parameters differ in general for different individuals. The aim of this study is to develop methodology for setting the parameters of tori obstacles based on magnetic resonance imaging (MRI) of a particular shoulder. That is, patient-specific approach is adopted.

The shoulder of a patient is investigated using MRI to obtain anatomy data regarding glenohumeral joint and relevant muscles, see Fig. 1. In fact, we use standard MRI scanning of a shoulder that is common in medical practice. To process these data, semi-automatic tool has been developed. It enables us to identify individual bones and muscles. In this particular application, we use it to identify humerus and the deltoid muscle. Consequently, we create a 3D geometrical representation of these tissues.

The deltoid muscle is represented in the model with several lines of action. To obtain these, section cuts of the 3D geometrical model of the deltoid muscle in corresponding planes are performed. For each section, centerline of the muscle is obtained, see Fig. 2. Here, the centerline is depicted as a green line. The crucial task is to represent this centreline with the line of action within the musculoskeletal model using a torus obstacle. In fact, an optimization method is used

Fig. 1. MRI scan of a shoulder (frontal plane).

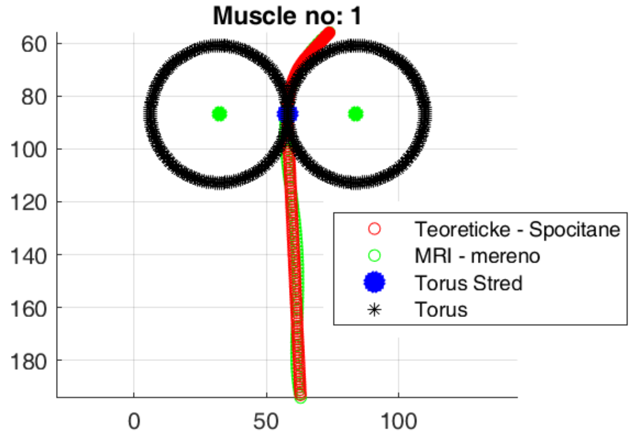

Fig. 2. The best fit of virtual muscle line (red) and a real centerline from MRI image (green) and the corresponding torus obstacle (black)

to find the parameters of the torus obstacle (position and radius) in order to find the best fit of the virtual muscle line and the real centerline. The result is depicted in Fig. 2. The virtual muscle line is depicted as a red line. The section of the corresponding torus obstacle is also depicted (black circles). The virtual line passes through the torus which has a zero inner diameter in this case.

The optimization process is done for each section cut. Hence, virtual lines of action and corresponding parameters of tori obstacles in terms of radii and positions are obtained. These are used as an input data for the musculoskeletal model of a shoulder in AMS. The proposed process is based on a patient-specific anatomy data. Hence, it contributes to the personalization of resulting musculoskeletal model.

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References

[1] Havelková, L., Špička, J., Vychytil, J., Aurbach, M., Krnoul, Z., Torus-obstacle method used for representing muscle path in musculoskeletal models, Proceedings of the 8th World Congress of Biomechanics, Dublin, 2018.

[2] Holtz, C., Global health care: Issues and policies, 2nd edition, Jones & Bartlett Learning, Burlington, MA, 2013.

[3] Huisstede, B., Complaints of the arm, neck and/or shoulder. A new approach to its terminology and classification: the CANS model, Ph.D. thesis, Erasmus University Medical Center, Rotterdam, 2007.