MODELLING OF SOFT TISSUES MORPHOLOGY AND KINEMATICS

[1,2]Fedor Moiseev, [1,2]Victor Sholukha, [1]Olivier Snoeck, [1]Stéphane Sobczak, [1]Véronique Feipel, [1]Jean-Louis Lufimpadio,

[1]Marcel Rooze, [3]Fulvia Taddei and [1]Serge Van Sint Jan

[1]Laboratory of Anatomy, Biomechanics and Organogenesis (LABO), Université Libre de Bruxelles (ULB), Belgium.
[2]Department of Applied Mathematics, SPbSPU, St Petersburg, Russia.
[3] Laboratory of Medical Technology, Istituti Ortopedici Rizzoli, Italy.

Email: fmoiseev@ulb.ac.be, web: www.ulb.ac.be/~anatemb

INTRODUCTION

This paper is presenting an approach for modelling of the human musculoskeletal (MS) system, including morphology and kinematics of both skeletal system (SkS) and soft tissues (ST). The presented approach is using heterogenous experimental data such CT scan, MRI and dissection results for morphology, motion capture and electrogoniomery for kinematics. The modelling technique is based on regression analysis, technical frames matching methods and spline approximations of the objects.

METHODS

The current method includes several previously-reported approaches and its modified and advanced versions [1,2]. A double-step registration method was used with 3D bone data, joint kinematics and motion data to obtain anatomically correct SkS behavior model [2]. We extended these results taking into account data about ST morphology, taken from MRI and dissection results, measured with specially developed stereophotogrammetric system [3]. These data were registered to the available SkS behavior model. Technical markers and technical frames matching methods were used for that purposes. Finding some inaccuracies in the matching of morphological data from different resources, we solved the problem by projecting the points measured during dissection on the MRI surfaces. With these results we used spline curve for the approximation of musle fibers and spline surfaces to interpolate between the fibers. This technique led to a model including morphology of SkS together with ST [1].

Further extension of model, including ST deformation, was based on the approximation of ST motion according to the underlying skeleton motion. First we extended the previous spline approximation of each muscle to more generic representation (i.e., B-spline volume). A B-spline object is parameterized using three independent variables. This allowed represention of full muscles, including external surface and internal fiber approximation. The next step was to define for each control point of this spline volume a set of weight coefficients, inversely proportional to the distances from the point to adjacent bones [1]. Using this weight coefficient, transformation of point during the motion as combination of bones transformations was made possible. This point by point technique gave as new form of the spline object during a given motion. As the muscle volume remains constant during contraction and joint motion, we applied a technique allows conserving of the initial muscle volume [4].

RESULTS AND DISCUSSION

The presented figures are illustrating the result of the steps: the morphological and kinematical model of SkS (Figure 1), morphological model of both SkS and ST (Figure 2) and final morphological and kinematical model for both parts of MS system (Figure 3). Analyzing the created model we compared these results with real measurement obtained during dissection taken for 4 different poses (Figure 4). The maximal deviation was less than 10 mm.

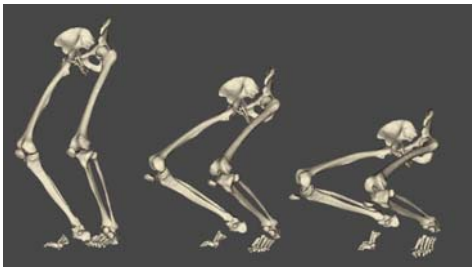

Figure 1: The model of the skeletal system, including morphological and kinematical data.

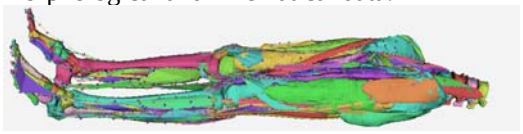

Figure 2: The morphological model of both skeletal system and soft tissues.

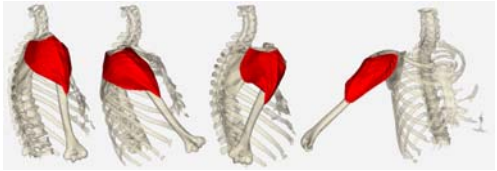

Figure 3: The result of soft tissue kinematics approximation.

Figure 4: Comparison of the developed approach with measurements.

CONCLUSIONS

The presented method allows creation of model relative to the morphology and kinematics of the main components of the MS system: SkS and ST. First validation of the results seems to show that this method lead to anatomically-acceptable models. Further improvements of the presented technique will take in account additional properties and constraints of the SkS and ST tissues.

ACKNOWLEDGEMENTS

This work was partly funded by the European Commission through the LHDL project (contract # IST-2004-026932).

REFERENCES

1. Moiseev F. et al. *J Biomech*. **41:**S204, 2008.
2. Sholukha V. et al. *J Biomech*. **39:**2087-2095, 2006.
3. Sholukha V. et al, *J Biomech.* **40**:S417, 2007.
4. Ng-Thow-Hing V., PhD thesis, 2001.