ADVANCED DATA CUSTOMIZATION PIPELINE FOR MOTION ANALYSIS AND MODELING

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INTRODUCTION

Accurate data customization is still a key issue in Biomechanics since it is a requirement for better data comparison (for example, during patient follow-up) and data fusion during integrated research [1]. For the last few years, the LABO has been working on several methods to improve data customization. This paper presents for the first time the entire data pipeline including the previously-developed methods combined into one protocol that can be used for fundamental or clinical research.

METHODS

Medical imaging (Low-Dosis CT – LDCT)

Bone and joint 3D representation is of high interest if one wishes to obtain accurate information on the local morphology and joint orientation of the subject undergoing the analysis. Computerized tomography (CT) medical imaging allows accurate 3D bone modeling. In order, to reduce ethical issues related to subject X-ray radiation Low-Dosis CT (LDCT) can be used without loosing 3D model surface resolution [2]. LDCT reduces the X-ray dosis absorbed by the patient up to 80% compared to standard CT sequences. LDCT use was recently approved by the Ethic Committee of the ULB Erasme hospital within an in-vivo motion analysis protocol (approval #P2008/284 – CCB: B40620084878).

Palpation (manual, virtual, A-Palp)

Palpation of anatomical landmarks is performed to allow 1) construction of anatomical technical frames for motion representation, and 2) registration of motion data to available 3D bone models. Palpation must follow strict definitions to reach higher accuracy and better reproducibility [3]. Therefore such definitions [4] have been adopted in this work for manual palpation of subjects undergoing motion analysis and, when LDCT imaging is available, for virtual palpation of 3D bone models. AL manual palpation is performed using a newly-developed finger gauntlet including a technical frame [5]. This gauntlet, called A-Palp, allows digitizing the pulp location of the palpating operator's finger during AL manual palpation. Such digitizing allows natural finger touching, while keeping satisfactory inter-session anatomical precision (in average - for the shoulder: 4.5 mm and 9.7 mm for intra-examiner and inter-examiner, respectively) [5].

Regression (multidimensional)

Joint center (JC) location is of importance for motion representation according to standards [6] and further musculoskeletal modeling (for example, to process a muscle moment arm). Functional methods are available [7]. Unfortunately, despite their usefulness with healthy volunteers, the motion pattern required by such methods is frequently too complicated for individuals with joint disorders. They are also limited to ball-and-socket joints. Therefore, methods based on regression are still necessary. Recent development related to multidimensional regression algorithms [8] have been extended to all major human bones and to all major joints. Combined to the availability of the above definitions and the A-Palp, the new regression method allows satisfactory in-vivo JC interpolation (e.g., less than 9 mm for the center of the humeral head). Further joint morphological estimation (e.g., size, shape, orientation) is also available from these methods [8].

Joint representation (double-Step registration)

Computer modeling of joints often reduces the number of available joint degrees-of-freedom (DOFs) to a minimal due to limitations of the data collection system (e.g., knee is systematically reduced to one or two DOFs). Such approach cannot guarantee the correctness of further musculoskeletal parameters. To try minimizing this drawback, a double-step registration method [9] allows a 6 DOFs mechanism joint models during in-vivo motion analysis.

Software interface (LhpBuilder)

The entire above data processing pipeline has been implemented into a customized software interface built from the open source MAF library [10]. Also see http://openmaf.cineca.it/maf/.

RESULTS AND DISCUSSION

Each single steps of the pipeline has been extensively validated (see related literature). The proposed method seems to be robust and should satisfy many research needs.

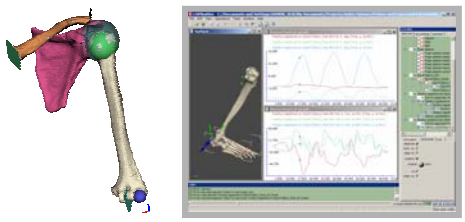

Figure 1: Left: results of regression algorithms for several joints (related to clavicle and humerus). Right: display of gait analysis after double-step registration. All images obtained from the LhpBuilder software.

CONCLUSIONS

Thanks to the LhpBuilder implementation, the above validated customization protocol is ready to be used by third parties and is available for distribution.

REFERENCES

1. Van Sint Jan S. *Critical Review of Physical and Rehabilitation Medicine*. **17:**249-274, 2005.
2. Van Sint Jan S, et al. *Clin Biomech*. **21:**992-998, 2006.
3. Van Sint Jan S, et al. *Clin Biomech*. **20:**659-660, 2005.
4. Van Sint Jan S Color Atlas of Skeletal landmark definitions. ISBN: 978-0443-10315-1. Elsevier, 2007.
5. Salvia P, et al. *Gait & Posture*. 2**9**:587-591, 2009.
6. Wu G, et al. *J Biomech*. **28:**1257-1261, 1995.
7. Camomilla V, et al. *J Biomech*. **39:**1096-1106, 2006.
8. Sholukha V, et al. *J Biomech*. **42:**319-324, 2009.
9. Sholukha V, et al. *J Biomech*. **39:**2087-2095, 2006.
10. Van Sint Jan S, et al. *Surg Radiol Anat*. **28:**518-524, 2006.