Specifications of a Software Framework to Position and Personalize Human Body Models

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I. INTRODUCTION

In passive safety, advanced Human Body Models (HBM) for injury prediction based on the Finite Element method have the potential to represent the population variability and to provide more accurate injury predictions than alternatives using global injury criteria. However, these advanced HBM are underutilized in industrial R&D. Possible reasons include difficulties to position the models – which are typically only available in one posture – in actual vehicle environments, and the limited representation of the population variability (size, weight, etc.). There has been multiple efforts in the past to position or personalize HBM but these have been generally model and code specific, limited in motion type and range, or simulation based (which can be time consuming for large models).

The main objective of the PIPER project (2013-2017) is to develop a "user friendly" software framework to position and personalize these advanced HBMs. The development was structured into three main topics corresponding to Work Packages (WP): the development of a modular software framework and numerical methods to transform the HBMs (WP3), the use of a priori knowledge regarding human body shape and posture to help define personalizing or positioning targets (WP2), and applications of the software to existing HBMs (incl. the GHBMC model, Thums V3, and child models that will be improved during the project [1]).

II. METHODS

The development was initiated with a specification phase. As user acceptance is critical for the success of the tools, a systematic online survey was developed to collect information about current practices and interest of potential users. It included 60 questions and 32 explanatory graphics. In parallel, a priori knowledge related to the definition of internal or external body shape or posture was reviewed and preliminary evaluations of various personalizing or positioning methods available at the project partners were conducted.

III. INITIAL FINDINGS

The survey was successfully carried out and responses from 189 users were received. All questions received a substantial number of answers allowing detailed analyses. More than 50% of the survey participants came from the industry which shows the high interest in the use of HBMs in industry. Key results included the need for FE code neutral approaches, the interest in global stature change (rather than localized model personalization), the priorities for positioning applications (e.g. Figure 1), statistics about current model sizes (median around 1 million element), time needed to position models, etc. All results of the poll can be found on the PIPER website (www.piper-project.eu) in an easy to understand graphical presentation.

The review of existing a priori knowledge put in evidence very large amounts of data related to body shape in the form of regressions and 1D anthropometry. However, despite numerous studies in the literature, publicly available 3D shape data usable for statistical shape analysis (e.g. using Principal Component Analyses) seem scarce, especially at the full body level. Other findings suggested that existing postural knowledge (e.g. distribution of motion in the spinal levels), in combination with positioning tools used in automotive ergonomics, could be useful to help improving the realism of postural targets.

Regarding numerical methods for the transformation of HBM, various interpolation functions (incl. Moving

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Least Square MLS and Kriging/Radial Basis Function), as well as contour based (e.g. [2]) and light physics based (Open Source Sofa Framework http://www.sofa-framework.org/) positioning approaches were tested. For personalizing, when performing stature/anthropometry changes on the GHBMC or child models, all interpolation methods could provide acceptable results in terms of time needed and element quality (e.g. Figure 2). The choice of control points seemed more critical than the formulation of the interpolation function itself. When performing local personalization of the ribcage shape, the best result (rib trajectory, respect of target) was obtained using MLS with biharmonic weight. However the computational cost on the full GHBMC model was close to 60 hours on a typical workstation, which would not be acceptable in most usage scenarios. Accepting errors on the target (e.g. 2mm RMS on rib geometry) allowed quicker computation with an acceptable element quality and without visible artefacts using for example Kriging with a nugget effect. For positioning, light physics based formulation seemed to be a promising approach to provide real-time realistic interaction models which can then be used to drive the position change (e.g. Figure 3). Contour based approach led to runnable models for the tested configurations. Beyond the choice of numerical approaches, the results highlighted the need for the model to be "positionable" (e.g. allowing soft tissue to follow the motion around the joints) to preserve element quality as much as possible without remeshing.

IV. DISCUSSION AND PERSPECTIVES

The specification phase is now completed and the active development phase is ongoing. Expected features and capability have been defined based on the poll, review and preliminary applications. The tools aim to be model and FE code neutral (with two codes and two full human models already used). The current development versions are written using C++, Python, Qt and the Sofa Framework among others, and run on Windows and Linux. The software will be released using the GPLv3 license to ensure easy access, allow future evolutions and contributions from the community as well as commercial services and support. Predictors of posture and shape will be based on statistical databases (e.g. geometrical) that will be released under a similar license. New data generation will mainly focus on full body skeletal geometry aiming to create full body statistical shape models.

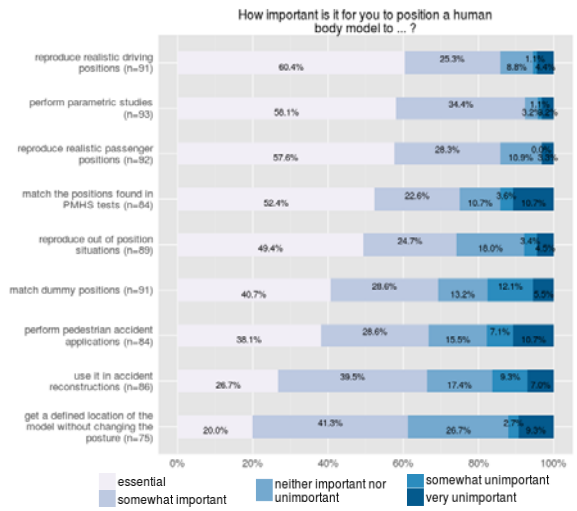

Figure 1: Example of answer in the user poll

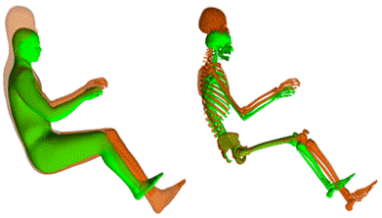
Figure 2: example of stature change using MLS interpolation (GHBMC M50 model to PMHS anthropometry)

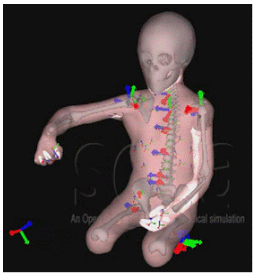
Figure 3: Shoulder positioning using the SOFA lightweight physics simulation (Child model: raising the right arm)

References

[1] Beillas et al., 2014. Ircobi Conf. [2] Jani et al., 2012. Traffic Inj. Prev.

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