

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

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I. INTRODUCTION

In passive safety, advanced Human Body Models (HBMs) for injury prediction based on the Finite Element (FE) 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 HBMs are underutilised 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 have been multiple efforts in the past to position or personalise HBMs, 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 personalise 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 personalising or positioning targets (WP2); and applications of the software to existing HBMs (incl. the GHBM 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 personalising 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 localised model personalisation), the priorities for positioning applications (e.g. Fig. 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 improve the realism of postural targets.

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Regarding numerical methods for the transformation of HBMs, various interpolation functions were tested (incl. Moving 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. For personalising, when performing stature/anthropometry changes on the GHBM or child models, all interpolation methods could provide acceptable results in terms of time needed and element quality (e.g. Fig. 2). The choice of control points seemed more critical than the formulation of the interpolation function itself. When performing local personalisation of the rib cage shape, the best result (rib trajectory, respect of target) was obtained using MLS with biharmonic weight. However, the computational cost on the full GHBM 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. 2 mm 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. Fig. 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) in order 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), which 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.

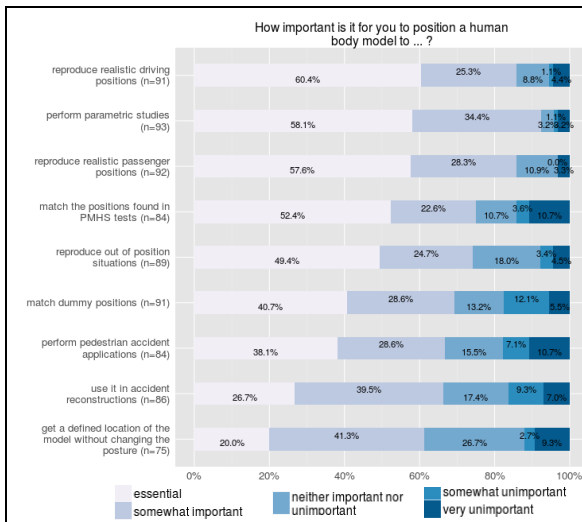


Fig. 1. Example of answer in the user poll.

Fig. 2. Example of stature change using MLS interpolation (GHBM M50 model to PMHS anthropometry).

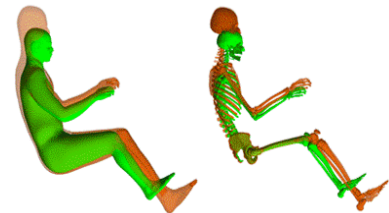
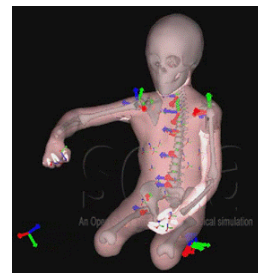


Fig. 3. Shoulder positioning using the SOFA lightweight physics simulation (Child model: raising the right arm).



V. REFERENCES

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

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