Comparison of methods for personalization of global human body models

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Problem.

Advanced Human Body Models, based on the Finite Element (FE) methods, have the potential to provide information complementary to those predicted with dummies or multi-body human models. If these full human body models allow to simulate the global response in a variety of impact conditions, taking into account the human variability in the context of injury prediction is still a challenge. Advanced FE models are only available for a few sizes corresponding to the dummies, and the development of additional ages/sizes models by standard procedures is costly. Recent efforts have focused on proposing methodologies for non-linear scaling of the Advanced FE models, using methods relatively common in biomechanical research or other fields. The PIPER project aims to develop new tools to position and personalize advanced Human Body Model (HBM) based on user-defined constraints and descriptors. Within that context, the aim of this study was to compare the performances of various interpolation methods to personalize the Advanced Human Body Models.

Methodology.

The methods tested were selected based on a literature review. They included Kriging/Radial Basis Function approach (Journel et al 1989)with various kernels and a relation approach (nugget effect), Moving Least Square with various weights schemes (Shungang et al. 2009). All were used to deform a model according to a target. The transformation was driven by landmarks. In order to facilitate the comparison of these methods in the HBM context, a set of scenarios and performance criteria were selected.

The scenarios represented different personalizing situations: i- the global change of stature of the adult GHBM M50 model according to anthropometric measurements performed on a post mortem 5th female subject, ii- the global change of stature of a child model (Beillas et al., Ircobi 2014) from 6 y.o. to 1.5 y.o according to a set of anthropometric dimensions from GEBOD, iii- the detailed personalization of the GHBM rib cage model to match a target based on CT-scan images (with the control of rib sectional area, dimensions and orientation).

Evaluation criteria included the time needed to deform the whole model, element quality (Scaled Jacobian and Shape & Size metrics), LS Dyna simulation (minimal time step, mass added, termination status), distance error to the target, distance between interpolated models and weight of thedeformed HBM.

Results and conclusion.

Regarding the application to perform the non-linear change of global stature (from 50th to 5th percentile, from 6 y.o. to 1.5 y.o) based on a few anthropometric dimensions, all tested methods (based on geometrical interpolation) provided acceptable results in terms of time needed for the deformation (a few minutes at most), overall respect of the targets, elements quality distribution and Ls-Dyna3D time step. The principal difficulty for this application was the definition of targets according to the inputs.

The personalization of rib cage proved to be much more challenging. None of the methods tested provided fully satisfactory results with a personalization at the level of the rib trajectory and section, with corrugated local deformations, except with a very specific MLS formulation leading to very high computational costs (over 60 hours). Approximate solutions could be obtained using Kriging formulations with a relation approach (Nugget). Such approaches may be sufficient within the context of impact biomechanics.

Overall, the results however highlight the importance of the target definition over the interpolation method and the need to integrate some relaxation in the process. It also provides information about computational costs compatible with interactive deformations.

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