Rapid Development of Finite Element Human Body Models to Represent a Diverse Population

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Background and Objective

Among the whole population, small female, obese, and/or older occupants are at increased risks of death and serious injury in motor-vehicle crashes compared with mid-size young male. Finite element (FE) human body models (HBMs) provide a valuable tool to better understand why these occupants are more vulnerable. However, it generally takes years to build and validate an FE HBM, thus current FE HBMs only represent occupants with the same body sizes and shapes represented by the anthropomorphic test devices (ATDs), in particular the midsize male and small female. Yet, the greatest potential for HBMs in vehicle development lies in representing the large range of human variability in geometry and response that are not represented by ATDs. Therefore, the objective of this study is to develop a method for rapid development of HMBs to represent a diverse population.

Methods

Figure 1 illustrates the process for rapid development of FE HBMs for a diverse population. It started with sampling the population with 100 occupants, followed by predicting the skeleton and external body shape geometries for those occupants using the statistical models developed previously, and ended with morphing a baseline mid-size male FE HBM into the target geometries for the 100 subjects.

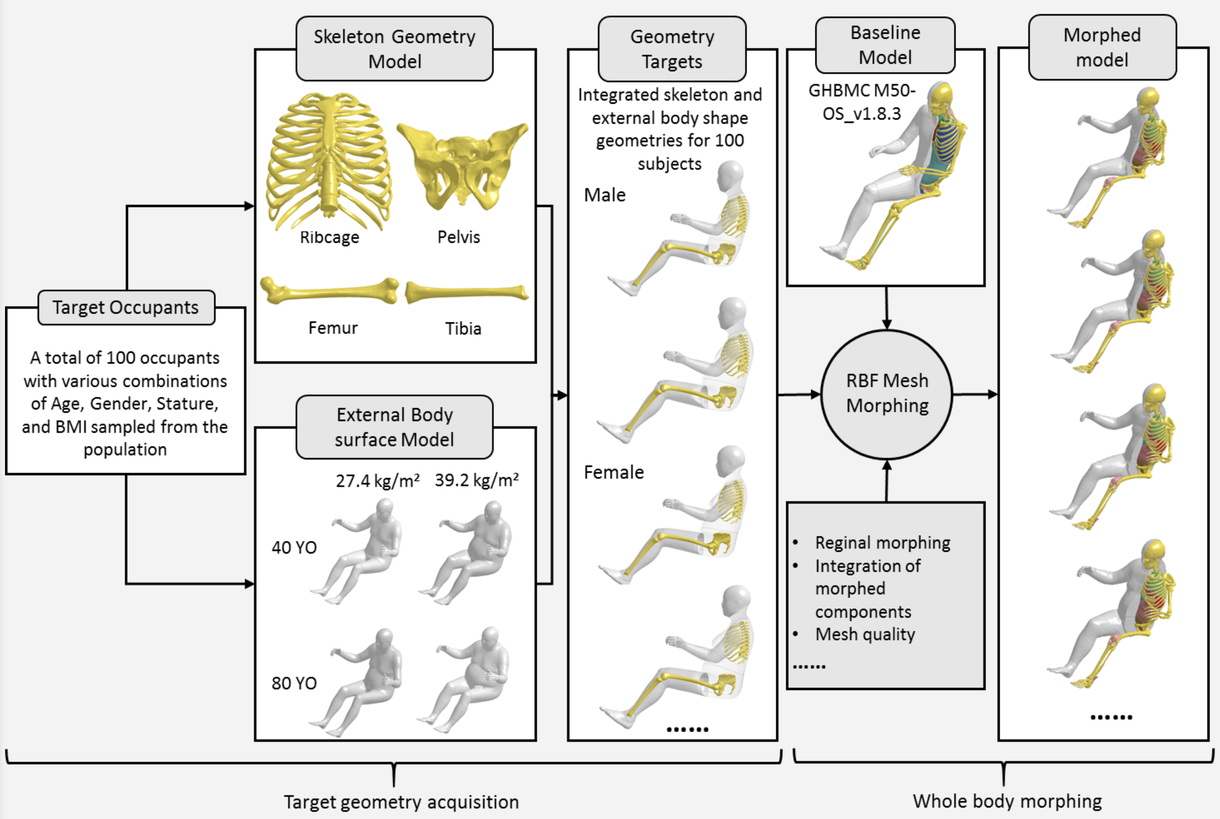

Figure 1. Process for rapid development of HBMs for a diverse population

➢ Occupant sampling and weighting

Anthropometry data from the National Health and Nutrition Examination Survey (NHANES) data from the years 2011-2014 was used for occupant sampling. Uniform Latin Hypercube Sampling (ULHS) method was used to sample 50 male and 50 female subjects based on age, stature and body mass index (BMI), and a weighting factor associated with each of the 100 sampled subjects was predicted.

➢ Statistical geometry models

The statistical skeleton geometry models, including the ribcage, pelvis, femur, and tibia, were previously developed based on CT scans from a total of over 300 subjects [1,2]. The statistical external body shape model was developed previously [3] and recently updated based on external body scan data from more than 200 volunteers. A rigid registration algorithm was used to position the bones into the external body surface based on limited body landmarks and joint centers that are available in the body shape model.

➢ Whole body morphing

A mesh morphing method using RBF-TPS (Radial Basis Function with Thin Plate Spline) was applied to rapidly morph the baseline model (GHBMC M50-OS) into the target geometry [4]. To reduce the time and memory, a regional mesh morphing strategy was proposed in Figure 2.

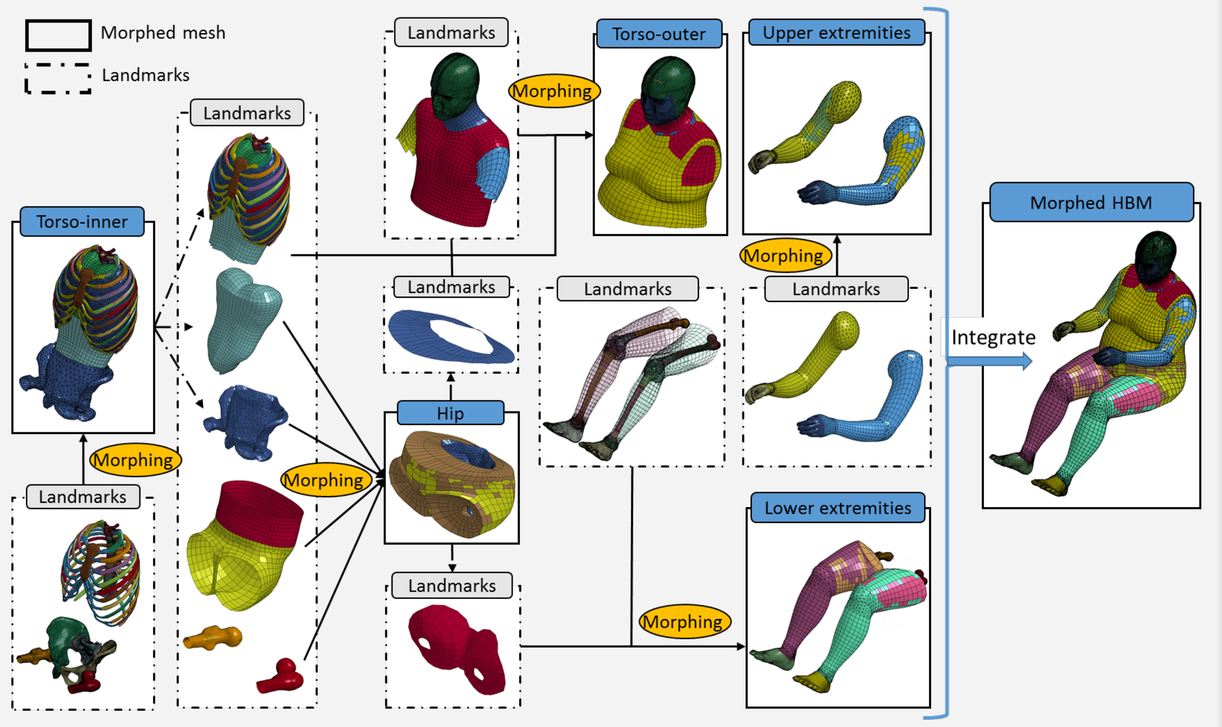

Figure 2. Whole body morphing by different body regions

Results

The entire morphing process to generate a subject-specific FE HBM was automated, and it took about 10 minutes in an 8-core PC without any manual intermediate steps.

Whole-body FE HBMs for 50 male and 50 female occupants with a wide range of age, stature and BMI were developed. Examples of the morphed HBMs are shown in Figure 3.

The morphed models matched the target geometries well and sustained similar mesh quality as that in the baseline model. Crash simulations with a subset of the models were performed and they all terminated normally.

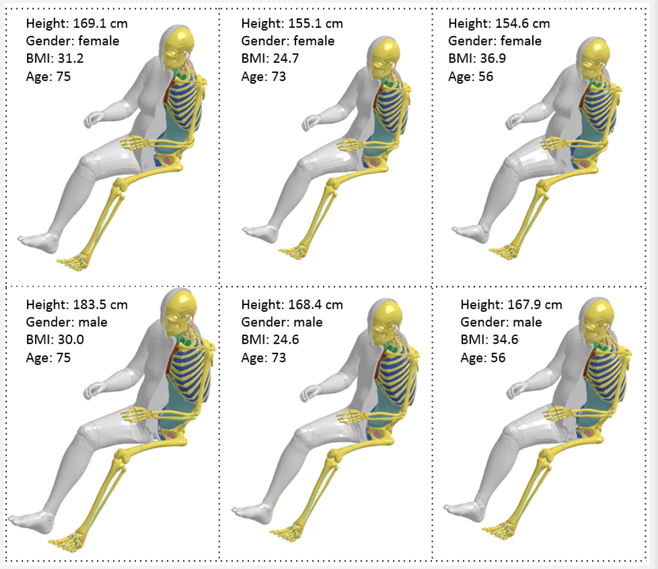

Figure 3. Morphed HBMs

Conclusions and Future Work

An automated procedure for rapid development of FE HBMs was proposed, and 100 HBMs representing occupants with a large range of human attributes were developed. These models will enable future studies on injury mechanism and occupant protection for different vulnerable populations.

Acknowledgements

This research is funded by National Science Foundation, General Motors (GM) and China Scholarship Council.

References

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