METHOD TO BUILD A STATISTICAL MODEL OF THE RIB CAGE MIXING MULTIPLE BONE POSE AND SHAPE FOR CRASH BIOMECHANICS

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Introduction

In passive safety, the state-of-the-art finite element human body models (FE-HBMs) used for injury prediction are available in 3 sizes only. But, for some applications like injury risk curves, an in-depth knowledge of the population variability is required. Thoracic injuries are a major cause of fatalities in motor vehicle crashes [1] and therefore precisely modeling the rib cage is critical. In recent years, many researches in the field of medical image analysis have focused on statistical shape modeling (SSM) for anatomical objects. Point Distribution Model (PDM) is a standard method for SSM [2,3] which represents the mean geometry and some statistical modes of variation inferred from a training set of shapes.

The challenge is that the rib cage is not a simple shape but is composed of 24 ribs articulated on 12 vertebrae and a sternum. Therefore, applying PDM does not allow capturing efficiently the variability of all the components.

The present work aims at defining a suitable SSM method for the rib cage complex geometry that separates the global structure variability due to different bone poses, and the intrinsic shape variability of each rib. This statistical model will be used to drive the deformation of a FE-HBM to capture variability in a population sample, and assess the influence of the pose and shape parameters on injuries in crash Finite Element simulations.

Method

A crucial requirement for a statistical analysis is the one-to-one correspondence between points for different shape instances. Therefore, a reference 3D mesh of a rib cage was semi-automatically registered [4] on a set of 26 CT-scans (73.3 ± 11 years old).

The SSM of the rib cage was developed with the following protocol. First the mean geometry was computed using a Generalized Procrustes Analysis (GPA). A multiple GPA was then applied on each bone separately to study the pose variability (i.e. differences of position and orientation) first, and the intrinsic shapes secondly.

The FE-HBM morphing was performed using control points with a dual kriging interpolation. The morphing was applied on the 50th percentile male global human body model (GHBM) to fit the mean geometry of the population studied and the variation modes according to the SSM.

Results

The method was applied to generate a virtual population [5,6] of morphed FE-HBMs according to the SSM. Illustrations in Fig.1 show how the population studied differs from the GHBM geometry.

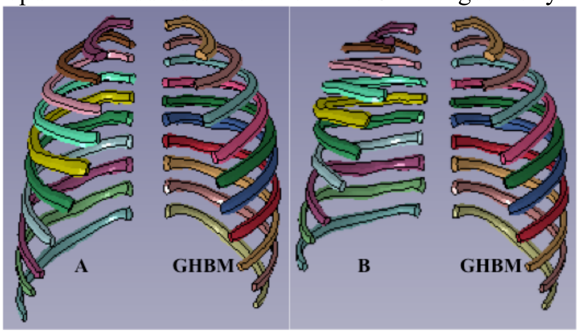

Figure 1: Comparison of the right side of our SSM with the left side of the GHBM. (A) Mean geometry. (B) Effect of the SSM first mode (+3σ along the first pose component).

Discussion

Full validation of this virtual population is still in progress, to assess the capability of morphed FE-HBMs to predict injuries. However, to our knowledge, this is the first study that proposes to fit a statistical multi-ribs model to the complex 3D rib cage geometry. In [6], it is shown that an average model does not always produce average results for non-linear simulations. This study could then open the way to a wide range of applications using SSM for biomechanical analysis mainly in automotive safety where the knowledge of the occupant anatomy variability is crucial. Therefore, it is planned to extend the method to a larger set of samples.

References

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