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

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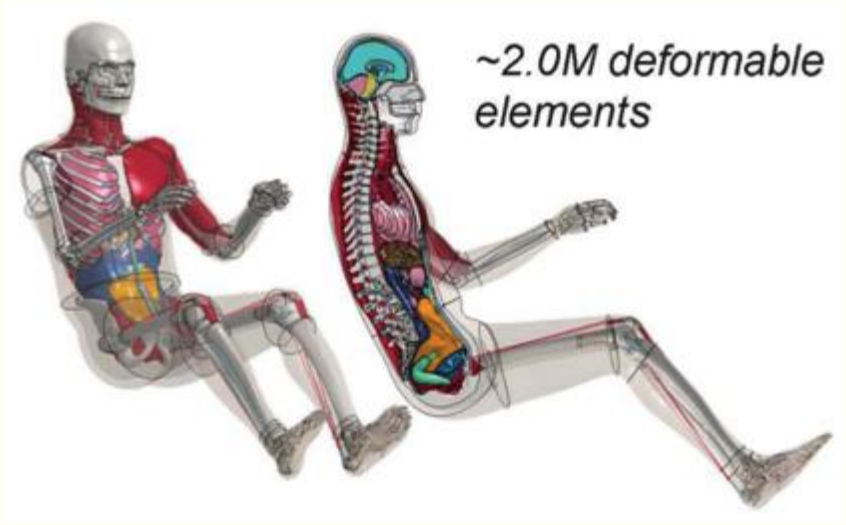
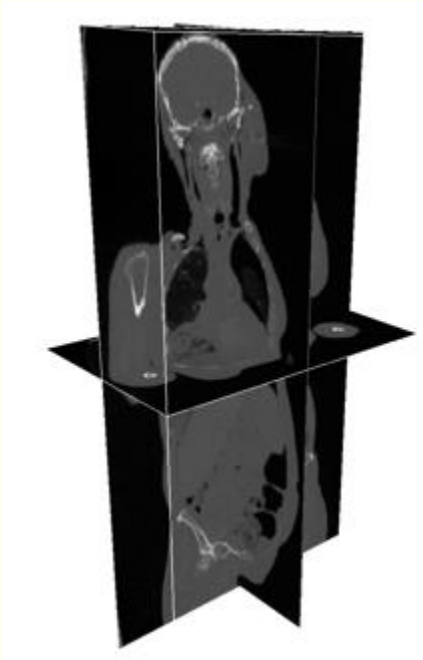
INTRODUCTION

- Context



Male 50th centile human body model for automotive crash simulations (www.ghbmc.com)



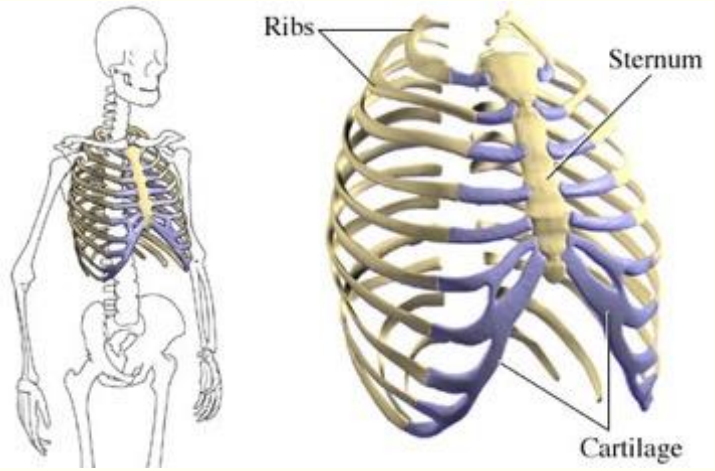
3D medical images – CT-scan to see inside body stuctures

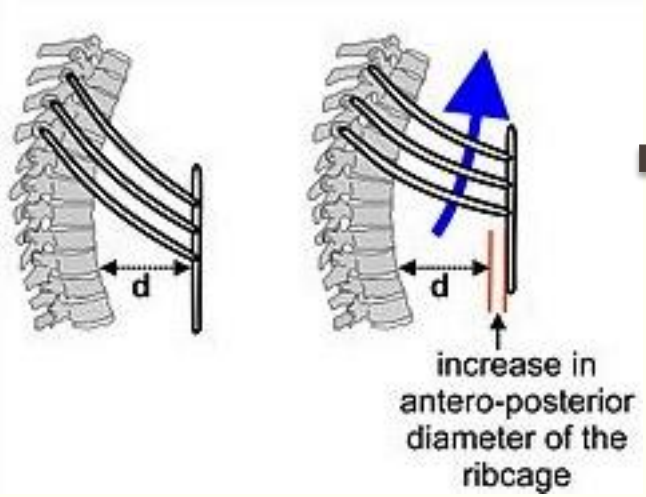
Human body shape variations *(Allen et al., 2003)*

Statistical analysis of morphology variations

INTRODUCTION

- Ribcage



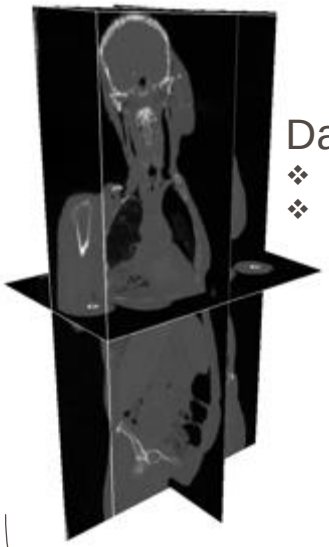


→ Articulated structure

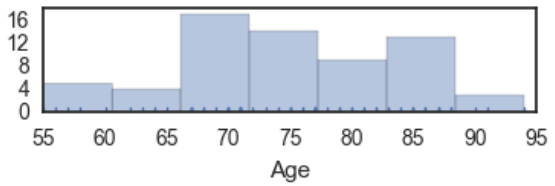
~~Common Statistical Shape Models~~

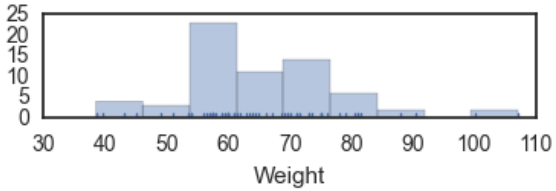
METHOD

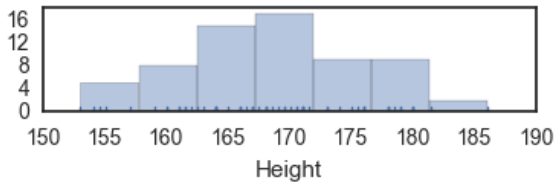
- Segmentation process



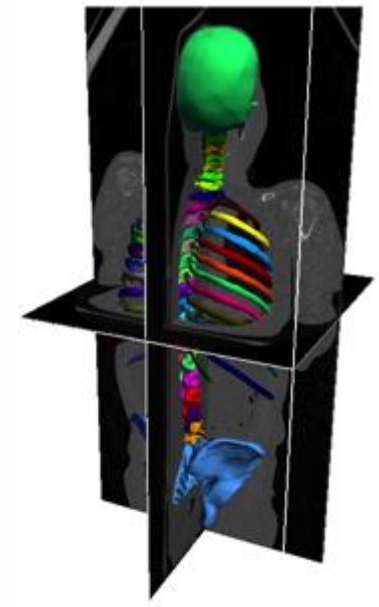
Database:
- 67 CT-scans
- voxel 0.97x0.97x0.5mm







Reference surface mesh



Deformation: mesh-to-image registration

(Gilles et al. 2010)

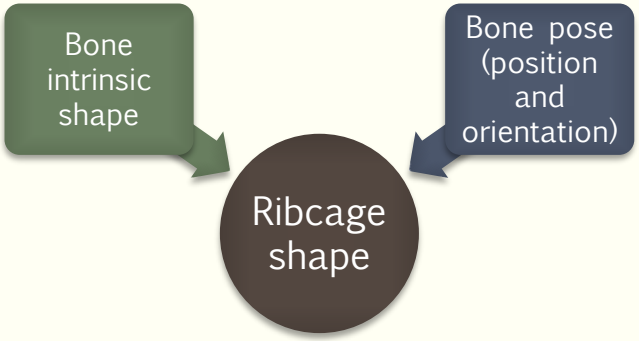
- ✓ Semi-automatic processing
- ✓ Point correspondence between subjects

http://www.anatoscope.com/

METHOD

❖ Multi-objects statistical shape model

Ribcages in the procruste frame

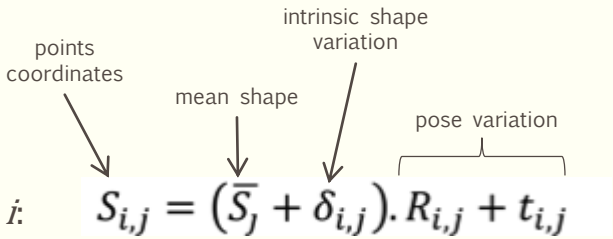


Multi-alignments:
each bone was aligned on the mean shape

Intrinsic shape variations
(points coordinates)
→ Principal Component Analysis
(Cootes et al. 1995)

Pose variations
(rigid transformations)
→ Principal Geodesic Analysis
PCA generalized for non-Euclidean spaces like the rigid transformations space
(Boisvert et al. 2008, Pennec 2006)

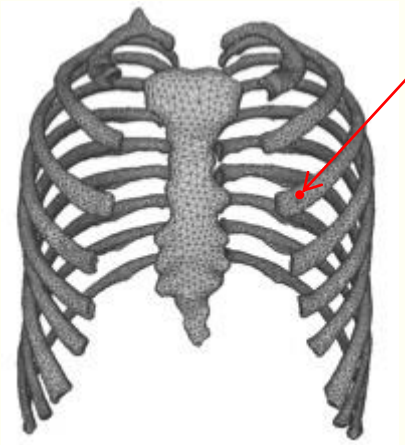
For a bone *j* from a subject *i*:



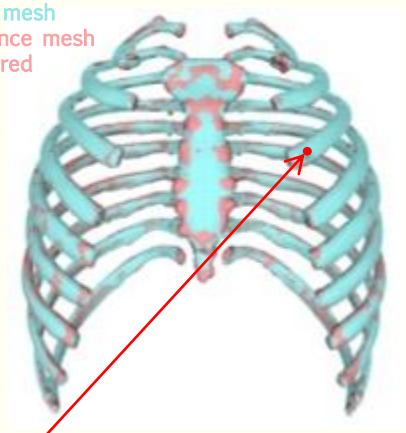
METHOD

❖ Kriging process

GHBM mesh
(finite elements human body model)



Reference mesh
(used to segment the database)



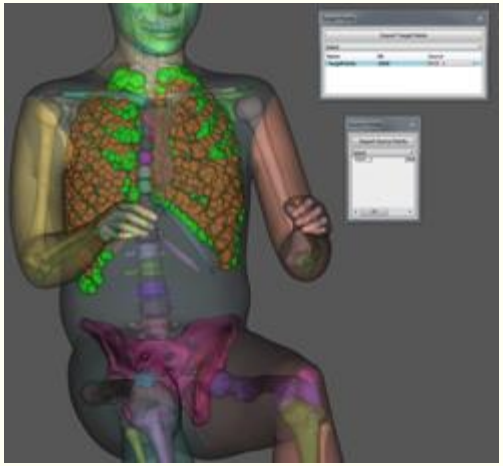
mesh-to-mesh registration

Link between both topologies

+

Point correspondence between subjects

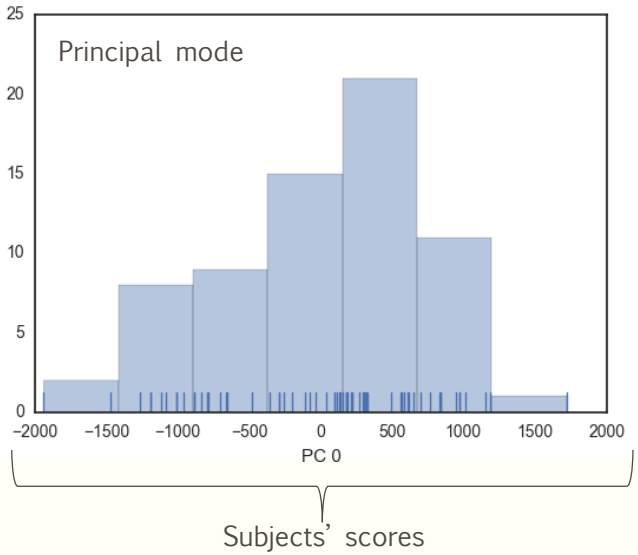
→ Easy way to define control points on the surface mesh



PIPER kriging module
(http://piper-project.org/)

RESULTS

❖ Statistical model



PGA
on pose variations

- PG : uncorrelated principal modes
- Subjects' scores associated with a PG

PCA
on intrinsic shape variations

- PC : uncorrelated principal modes
- Subjects' scores associated with a PC

Multiple Linear Regressions (MLR)

X : PGA scores
Y : PCA scores

Intrinsic shapes modes	PC 01	PC 02	PC 03	PC 04	PC 05	PC 06	PC 07	PC 08	PC 09	PC 10
R^2	0.93	0.81	0.80	0.68	0.79	0.84	0.63	0.79	0.70	0.70

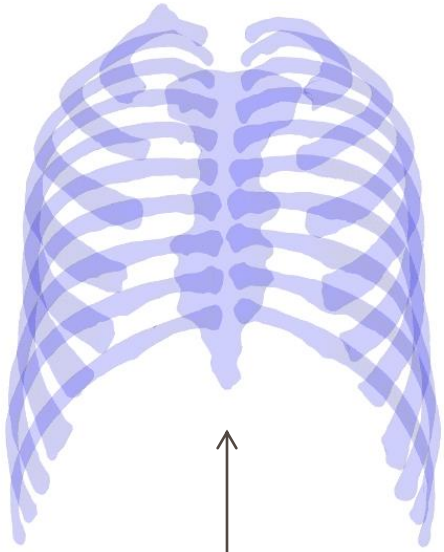
Knowing a rib pose, its shape is given by the MLR with a small error

RESULTS

- First PGA mode (pose variations)

First PGA mode from -3SD to +3SD

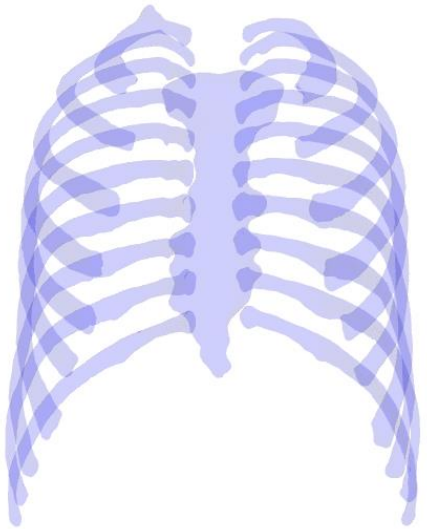
only rigid transformations



Issue with costovertebral joints

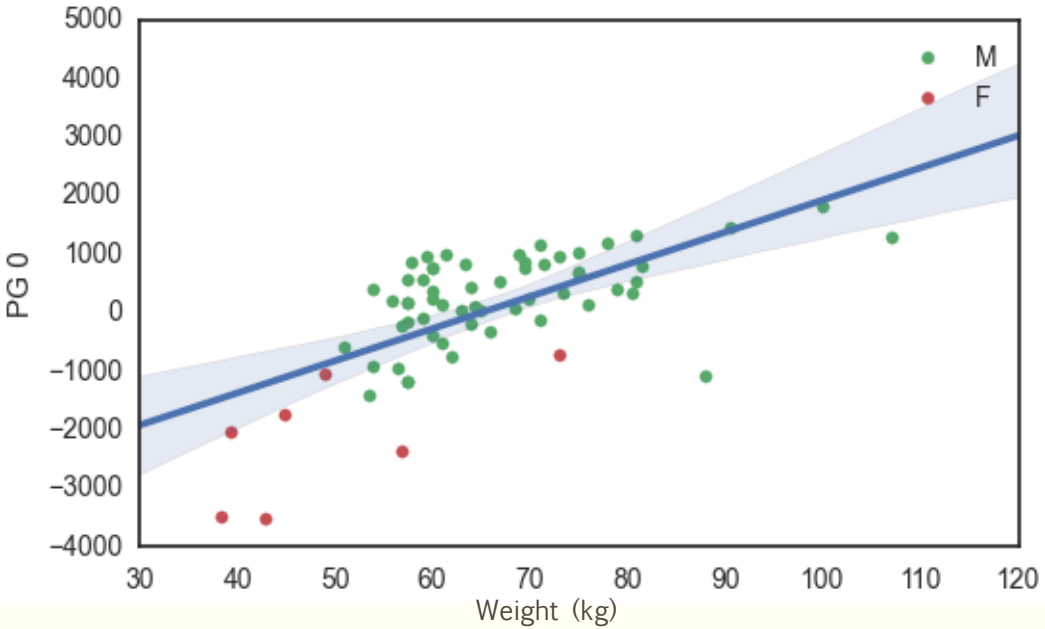
First PGA mode from -3SD to +3SD

rigid transformations + shape predicted by MLR



RESULTS

❖ Anthropometry



Multiple Linear Regressions (MLR)

X : Age, Weight, Height
Y : Fisrt PGA scores

$R^2 = 0.5$

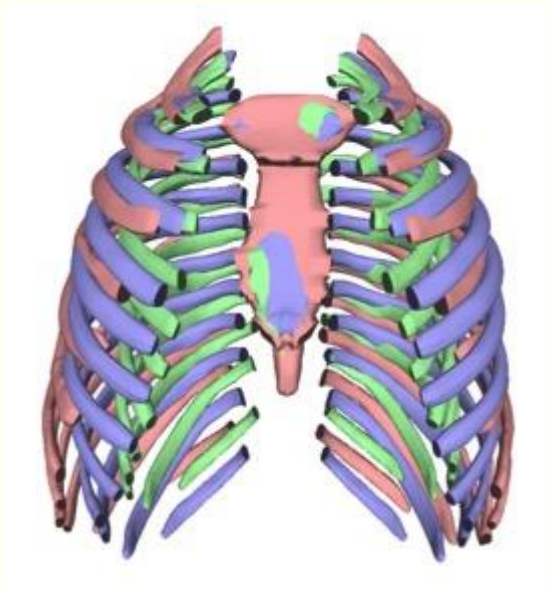
	coef	std err	t	P>|t|
const	-1.172e+04	2939.228	-3.987	0.000
Height	49.5923	18.334	2.705	0.009
Weight	33.5016	10.811	3.099	0.003
Age	15.6417	11.033	1.418	0.161

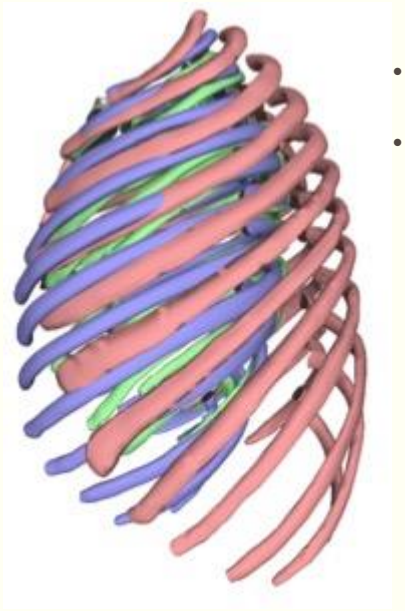
Statistically significant

RESULTS

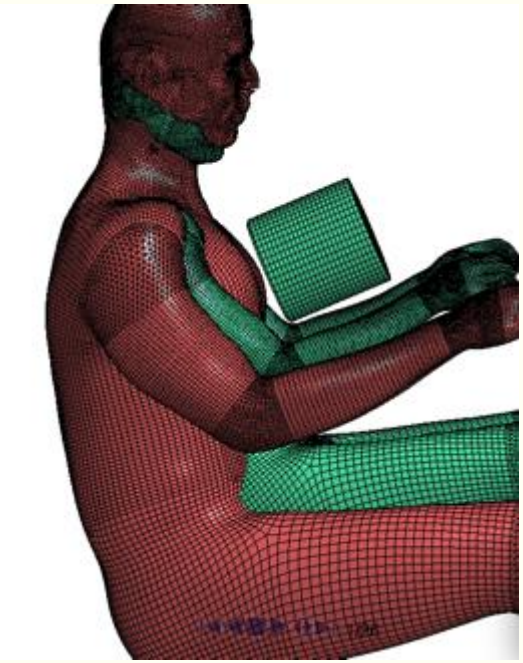
❖ Personalization for impactor simulation

- GHBM morphology
- +3SD first mode
- -3SD first mode

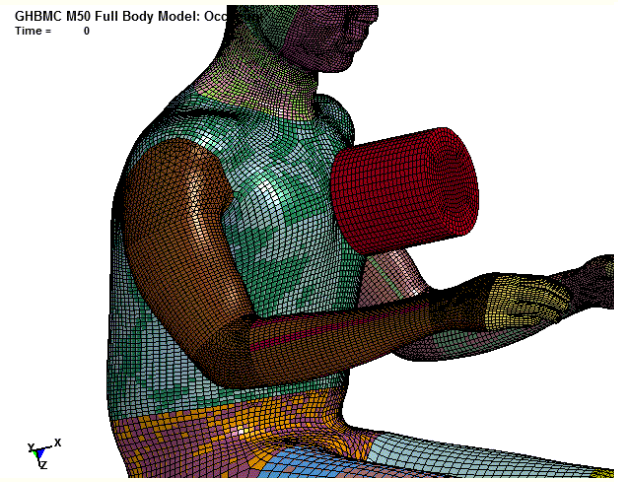




- 100 control points per bone
- Sternum as reference for positioning



Impactor:
- 23.4 kg
- 4.4 m/s

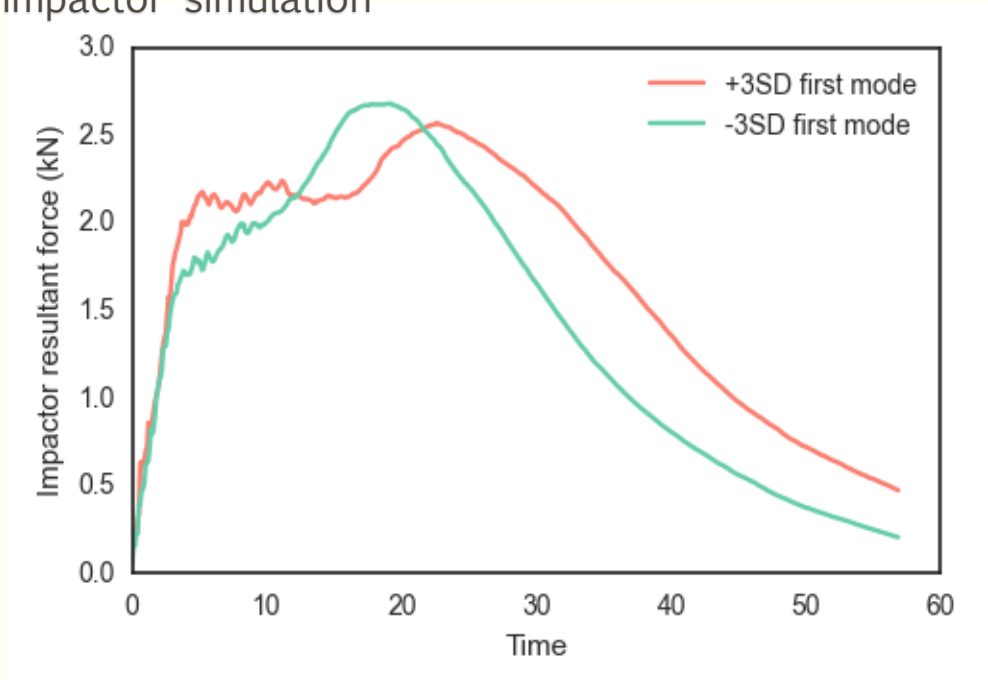


+3SD first mode

-3SD first mode

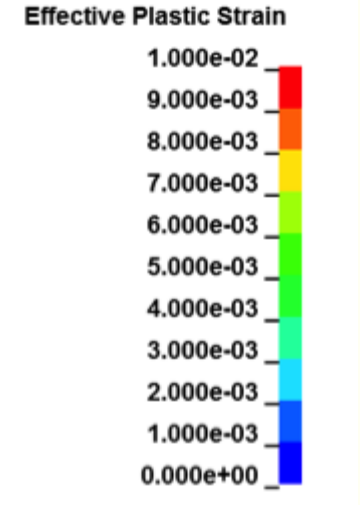
RESULTS

- Personalization for impactor simulation



+3SD first mode

-3SD first mode



CONCLUSION

❖ Discussion

- Dataset of old subjects
- Small mistakes on the reference mesh are present in all segmentations
- Kriging: soft tissues are interpolated
- Cortical bone thickness can't be assessed on CT-scans (resolution)

- A statistical multi-ribs model of the complex 3D rib cage geometry
- Process to apply statistical model on crash simulation
- Study the effect of weight or height on the thorax tolerance