Human Body Models customization by advanced mesh morphing: parametric THUMS

Master's degree in Mechanical Engineering A.Y. 2022/2023

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STUDENT GRADUATING

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Introduction

- Vehicle safety: injury predictions

- Injury prediction tools

- Crash tests: **ATDs**
(Anthropometric
test devices)

Introduction

- Vehicle safety: injury predictions

- Injury prediction tools
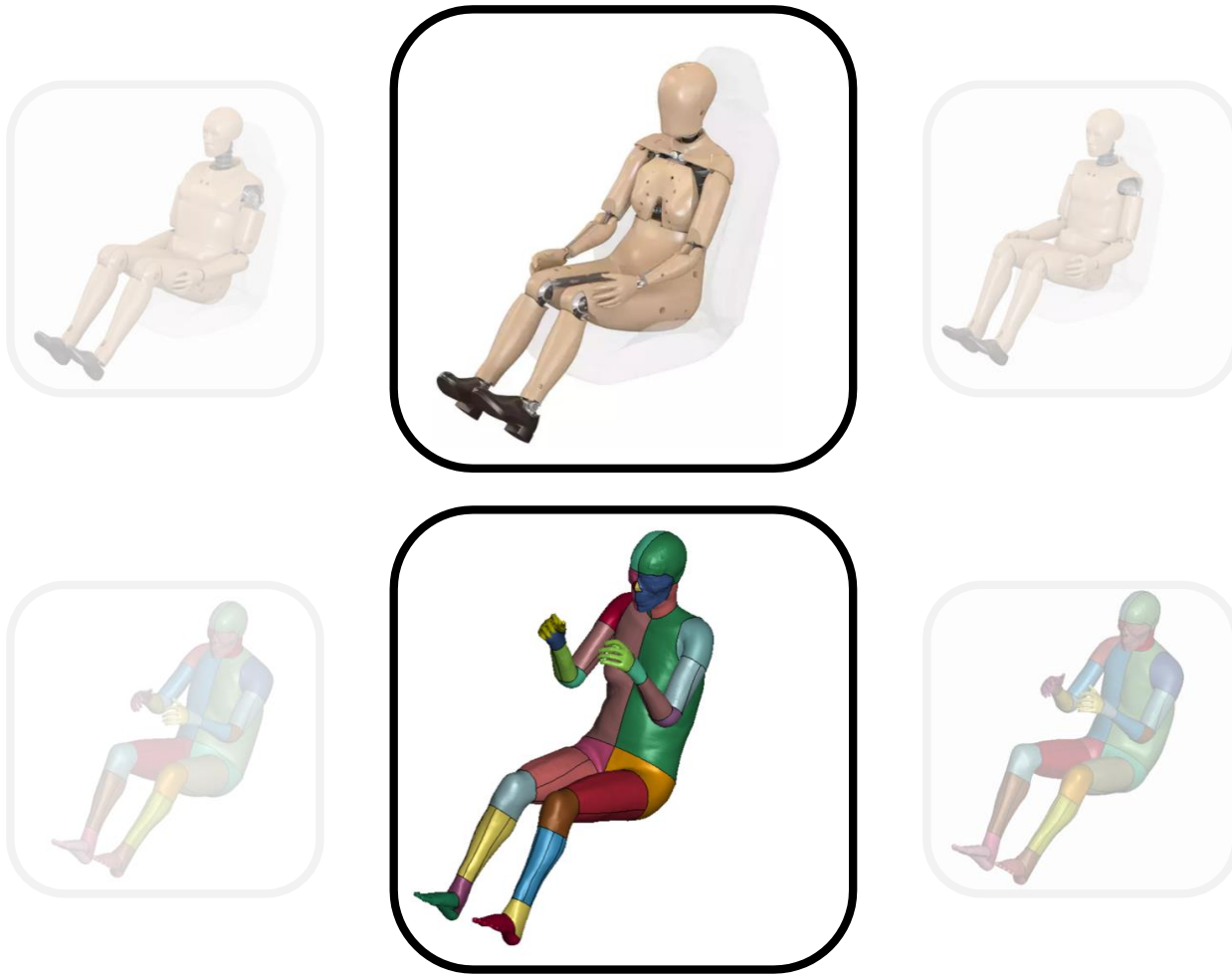
- Crash tests: **HBMs**
  (Human body
  Models)

HBMs vs ATDs

✅ Complete Anatomy→ accuracy

✅ Omnidirectionality → Flexible usage
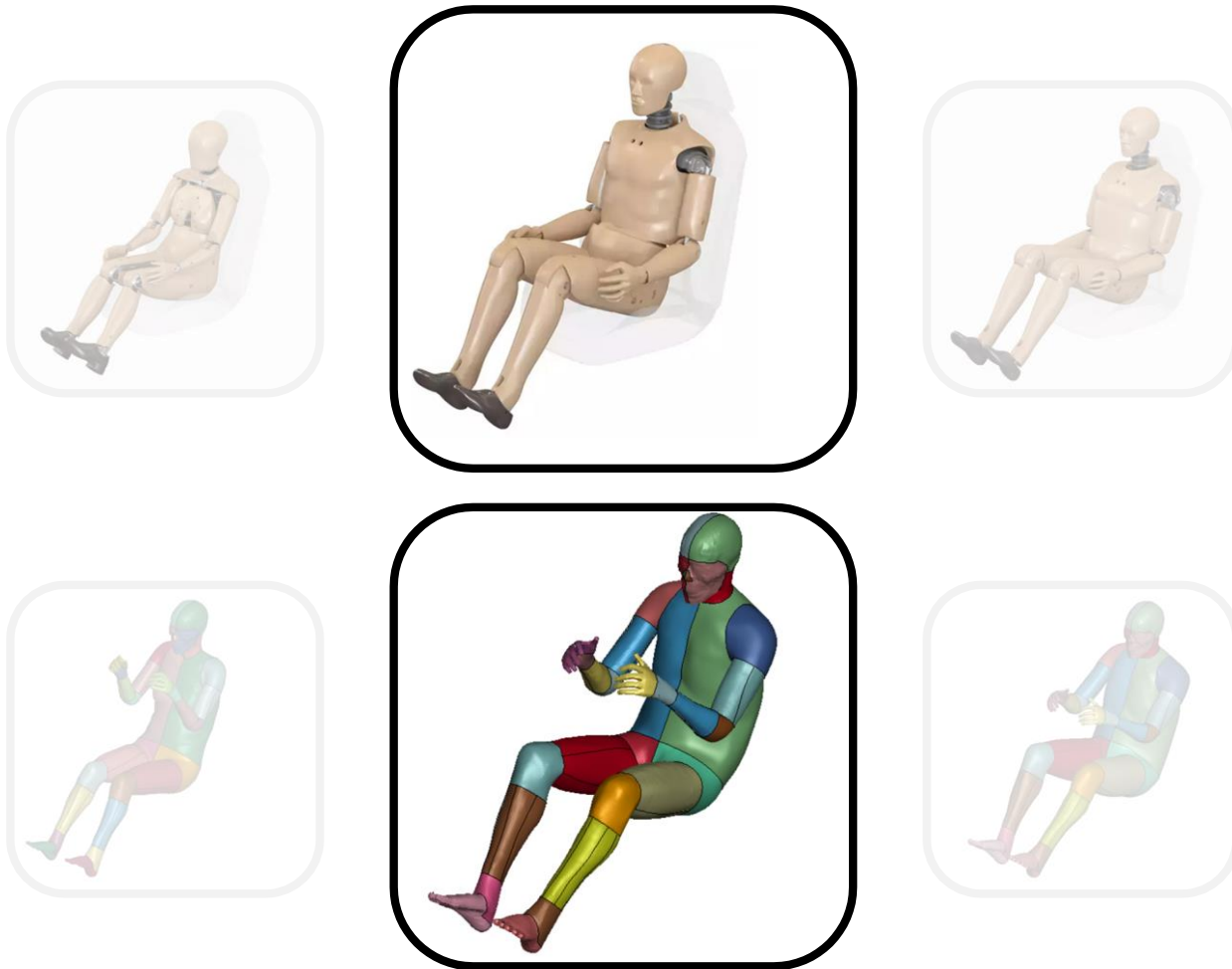
⚠️ Small number of shape avaiable

Small number of shape

Small size adult female

- Shape corresponding to the 5th statistical anthropometric percentile
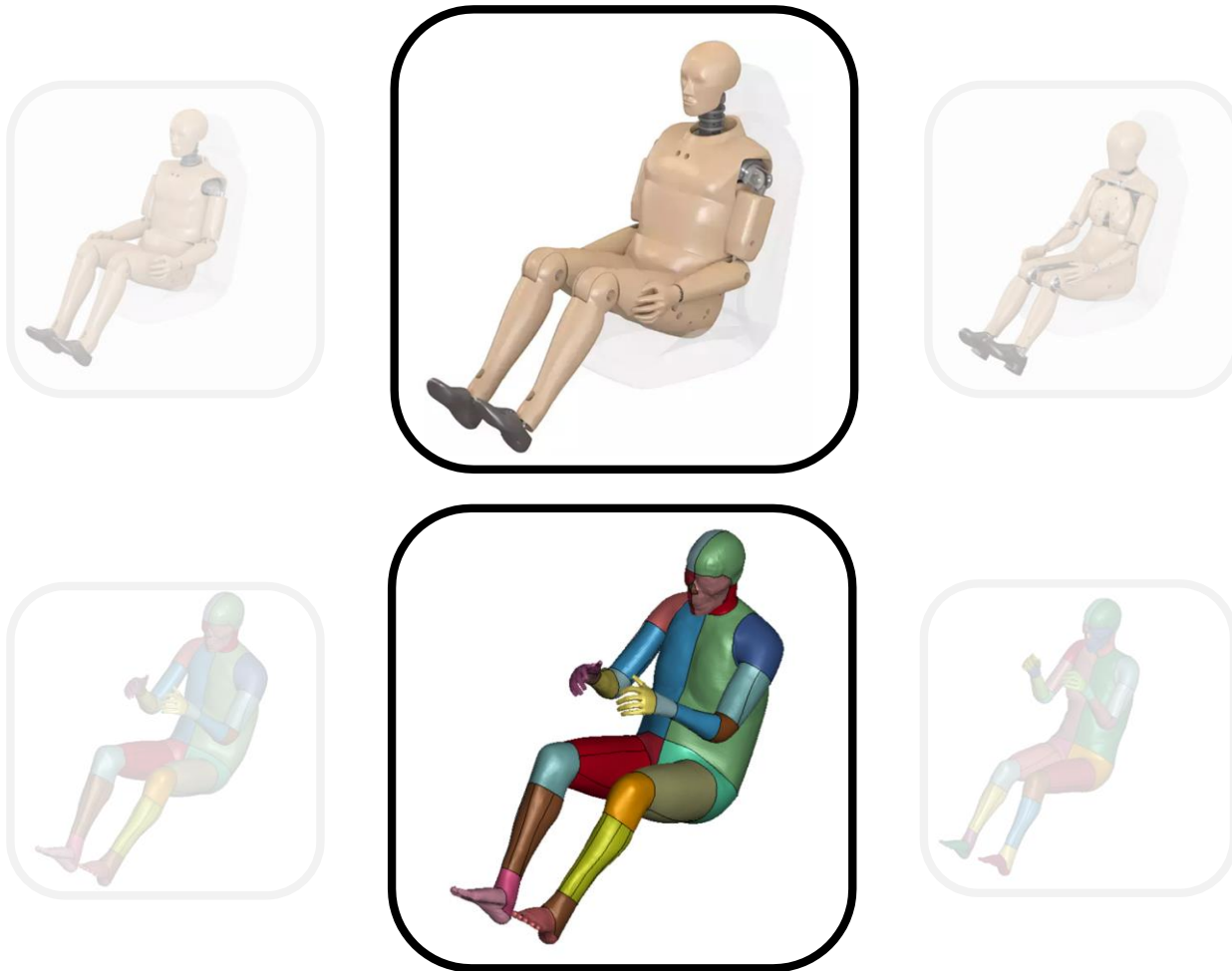
Small number of shape

Middle size adult male

- Shape corresponding to the 50th statistical anthropometric percentile
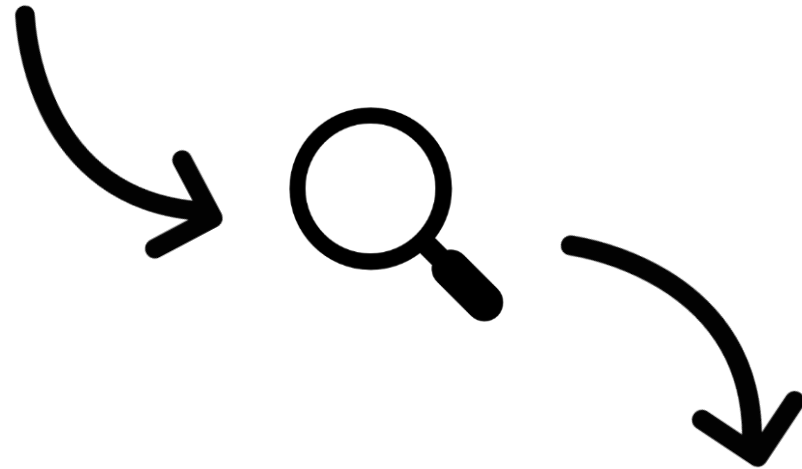
Small number of shape

Large size adult male

- Shape corresponding to the 95th statistical anthropometric percentile

Small range of shape

- In the development of HBMs, most antrhopometric shapes have ramained inexplored
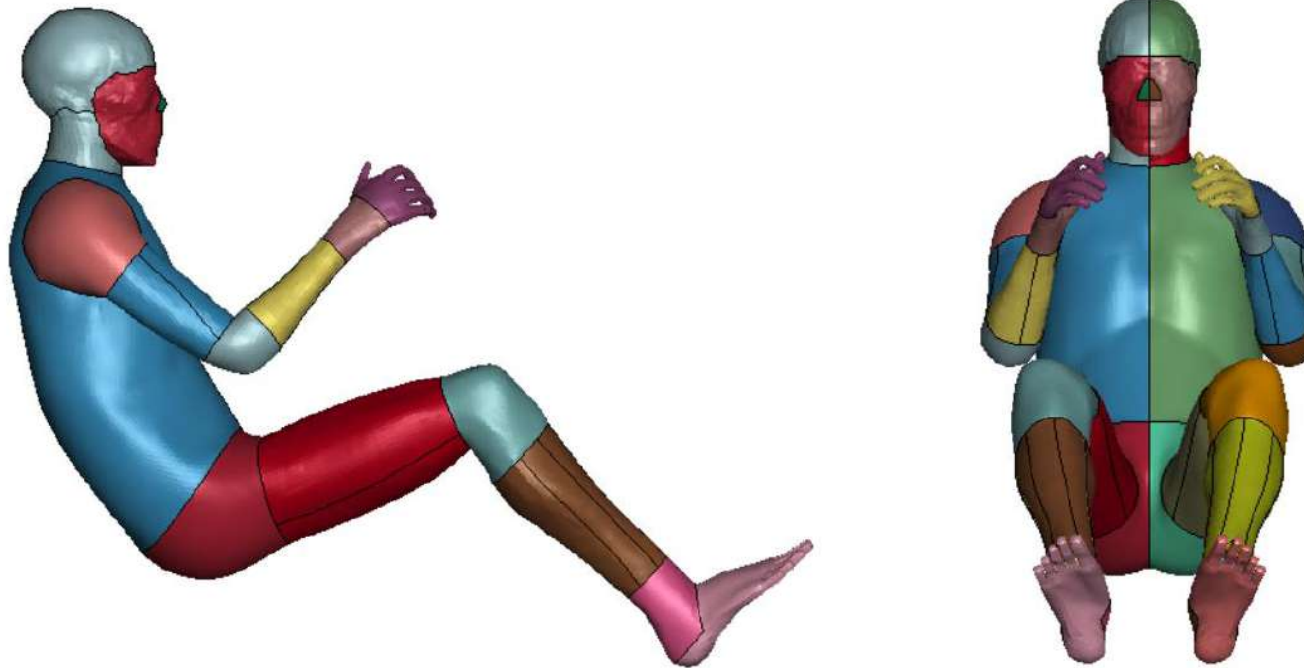

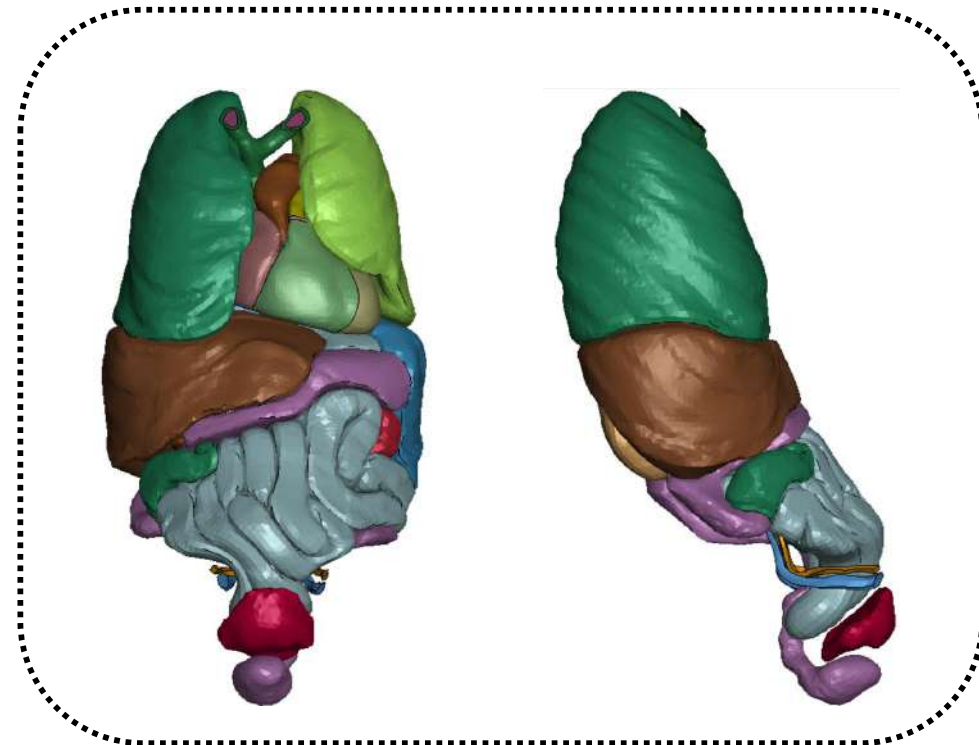**Human Body Models customization**
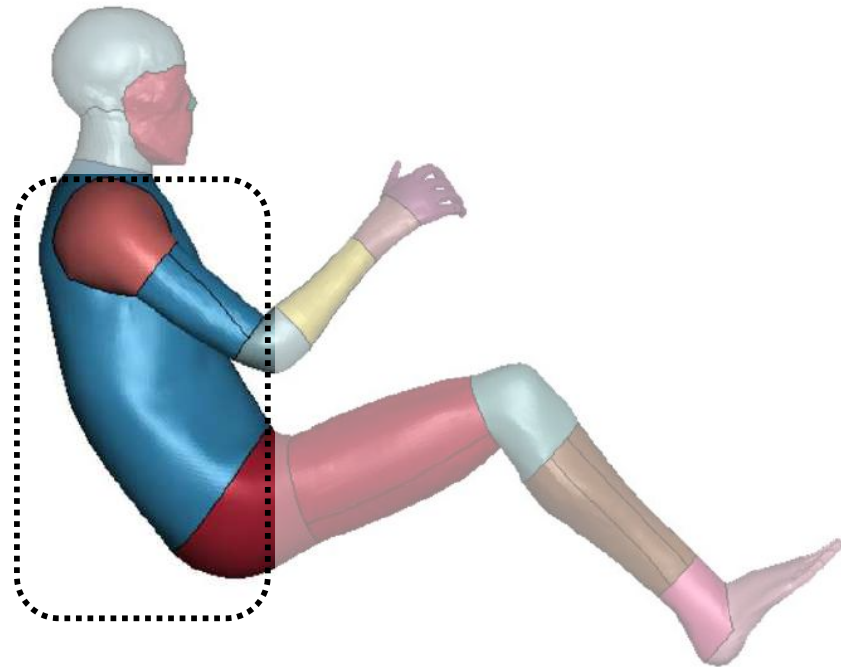
Total Human Model for Safety: Thums™

- Developed by TOYOTA → open source since 2021
- Advanced features

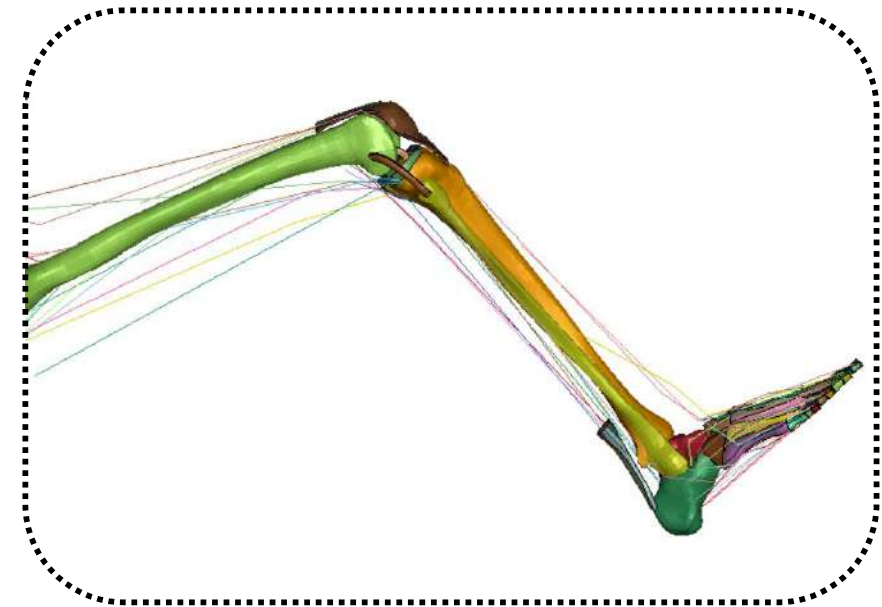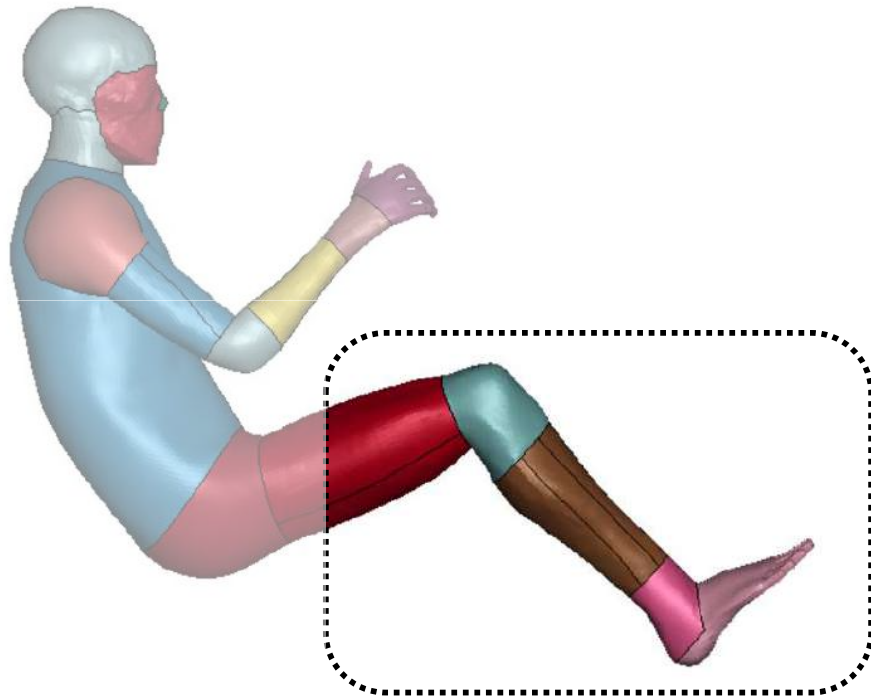# Total Human Model for Safety: Thums™

- **Internal organs** geometry extremely detailed
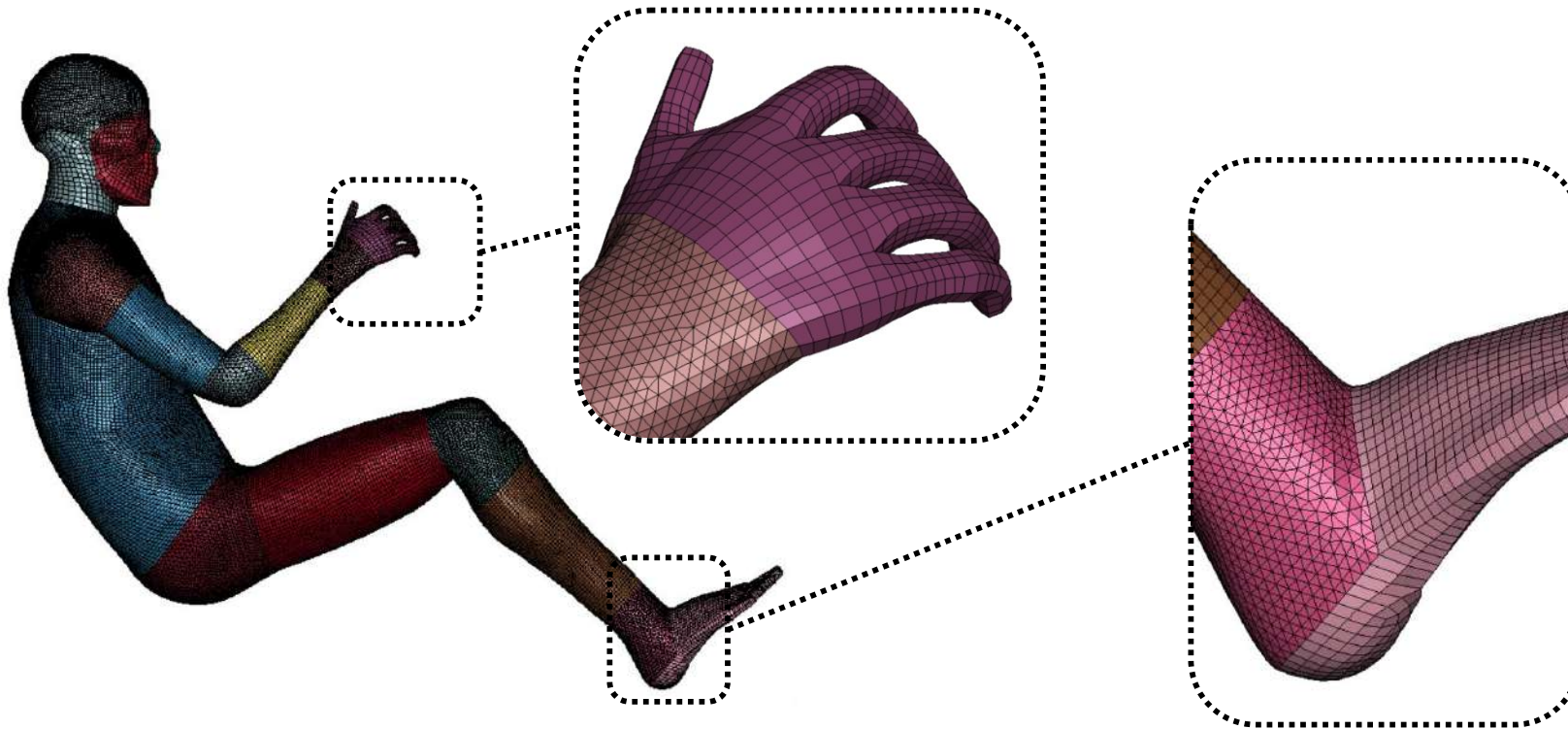
Total Human Model for Safety: Thums™

- **Complete modeling of muscolar function** through one-dimensional elements activated by feedback controllers
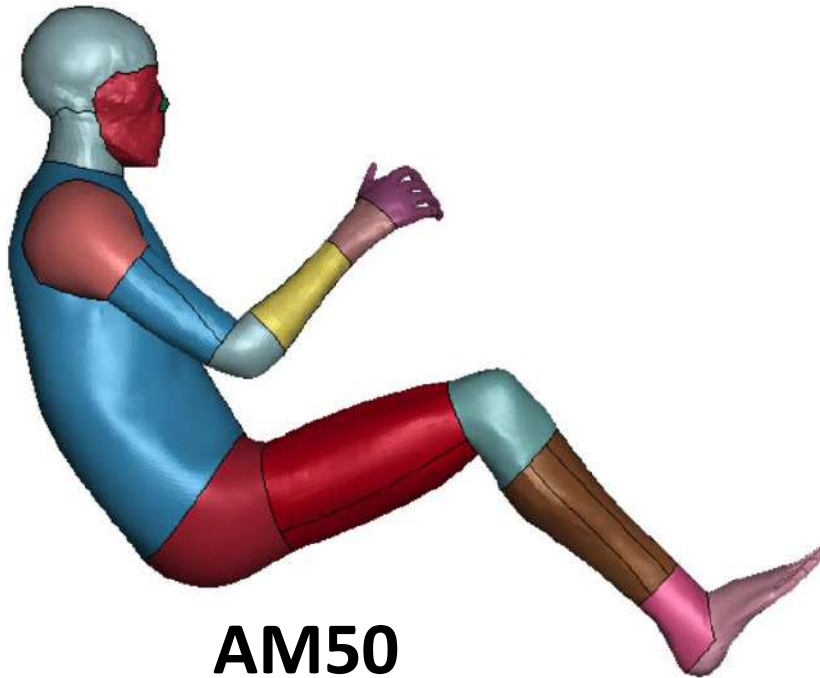
Total Human Model for Safety: Thums™
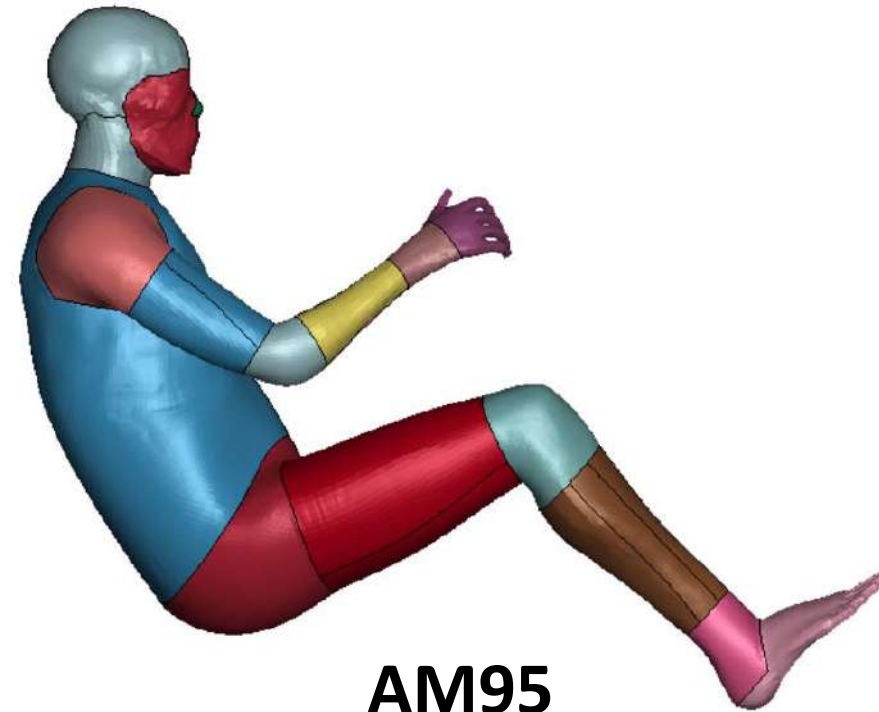
- **Mesh** composed of over **2 milion elements**

Total Human Model for Safety: Thums ™

- Unique shapes avaiable for male models: 50th e 95th statistical anthopometric percentile

AM50

AM95

Objective

- **Define** a method to create **THUMS** corresponding to the **generic percentile**
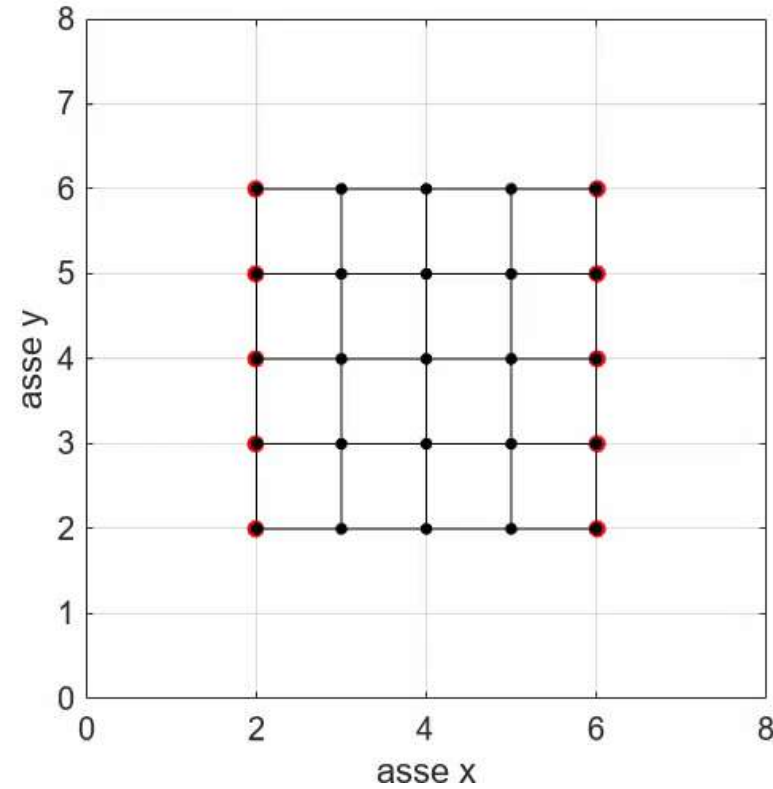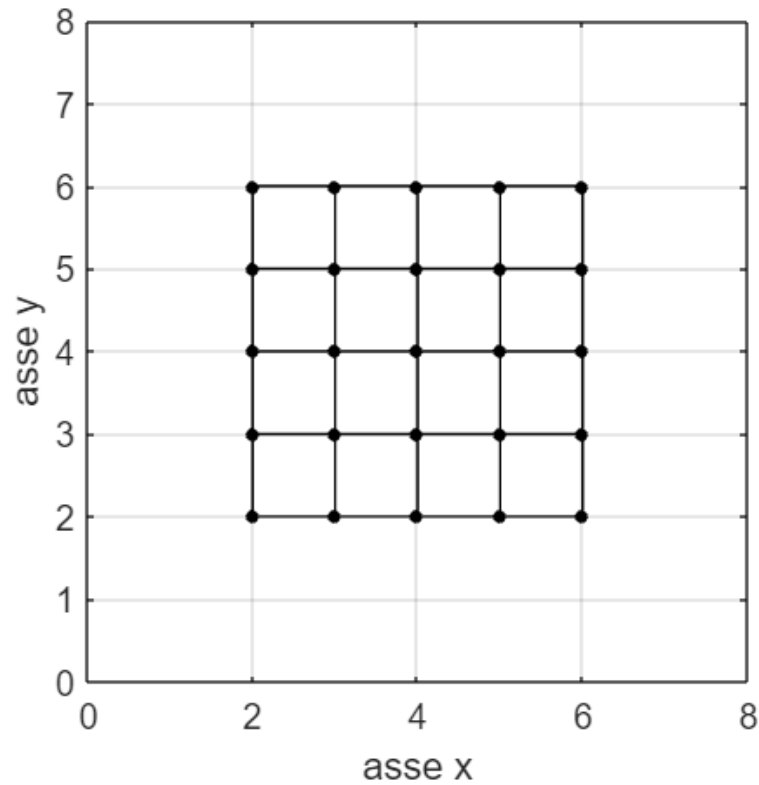
$$? \longrightarrow$$

RBF mesh morphing

Through RBF mesh morphing, it is possible to modify a discretized geometry by imposing the displacement of a certain number of its nodes
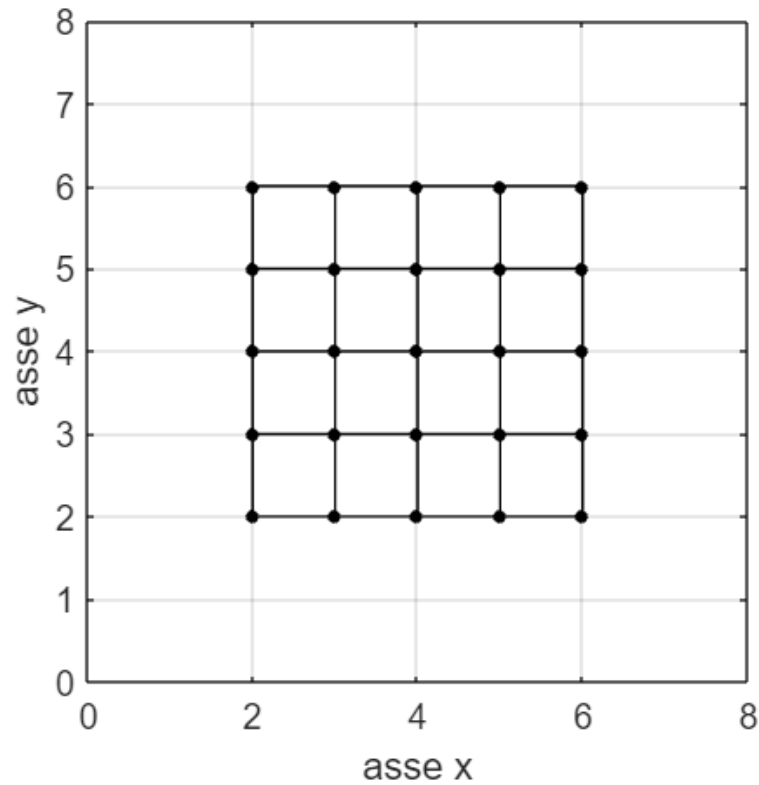
Mesh Morphing driven by RBF
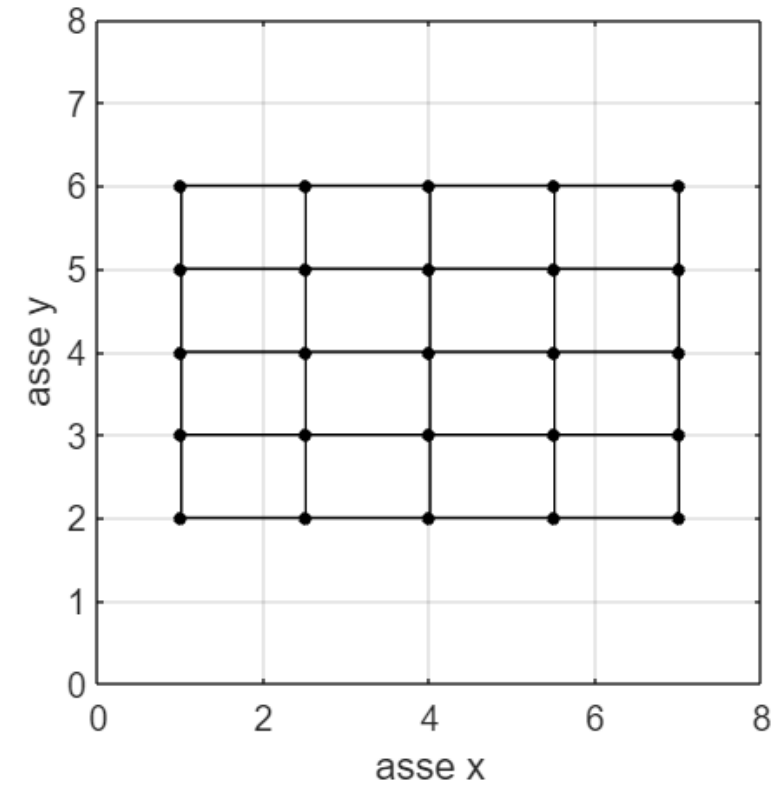
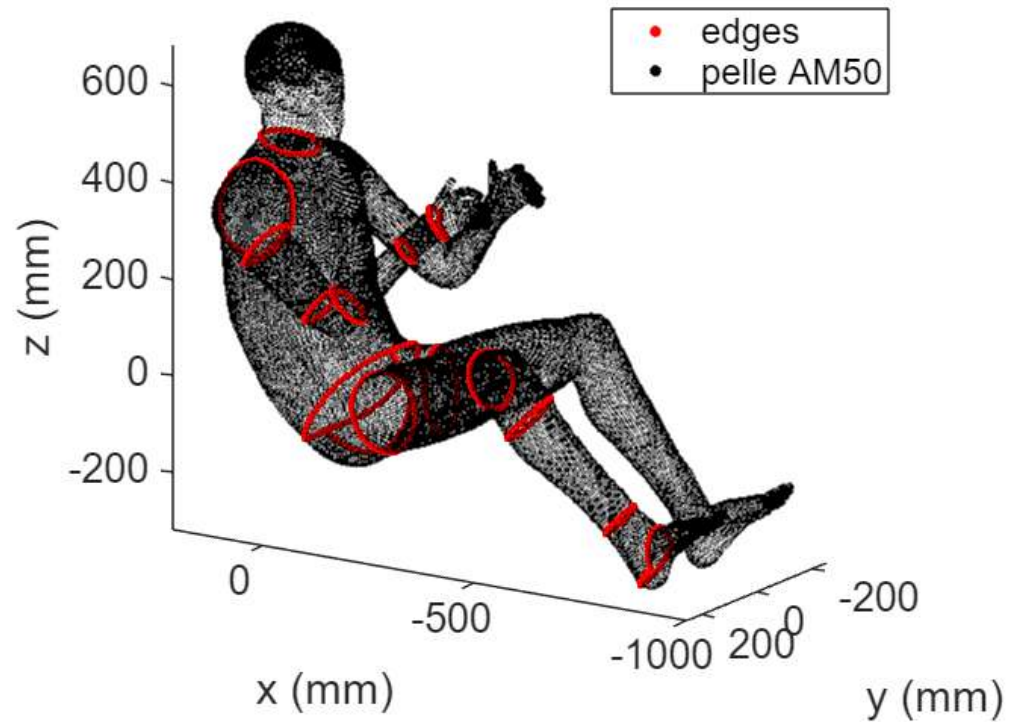**Example:**

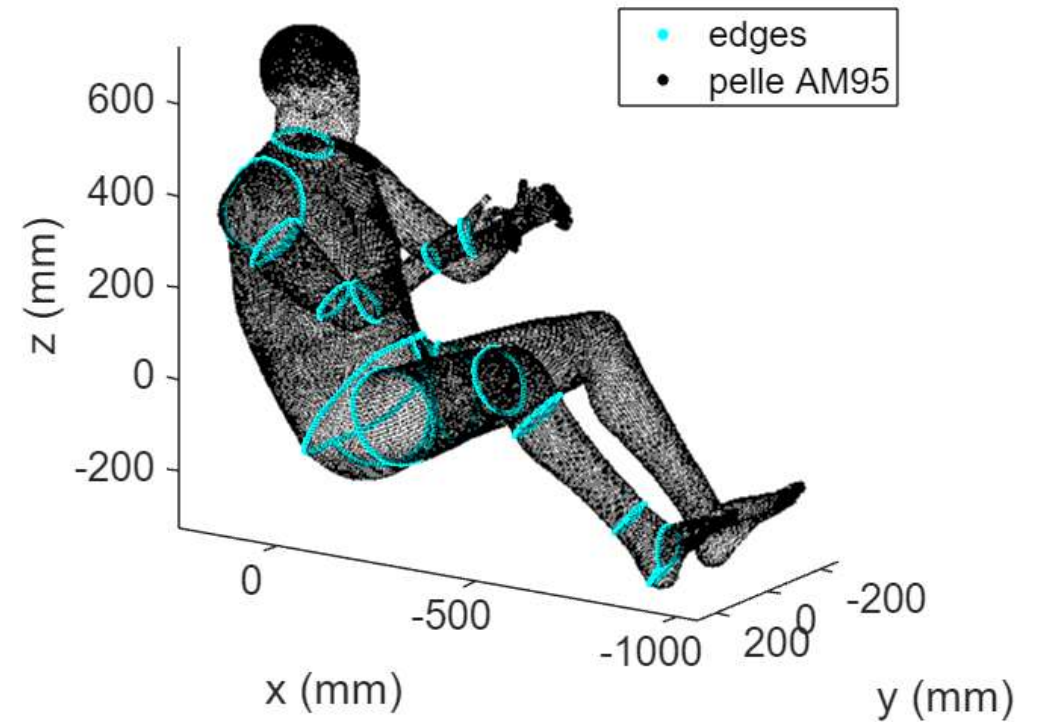# Mesh Morphing driven by RBF

Example:

RBF

Source points selection

- Source points in AM50

- Homologous edges in AM95

RBF displacements

- Translation
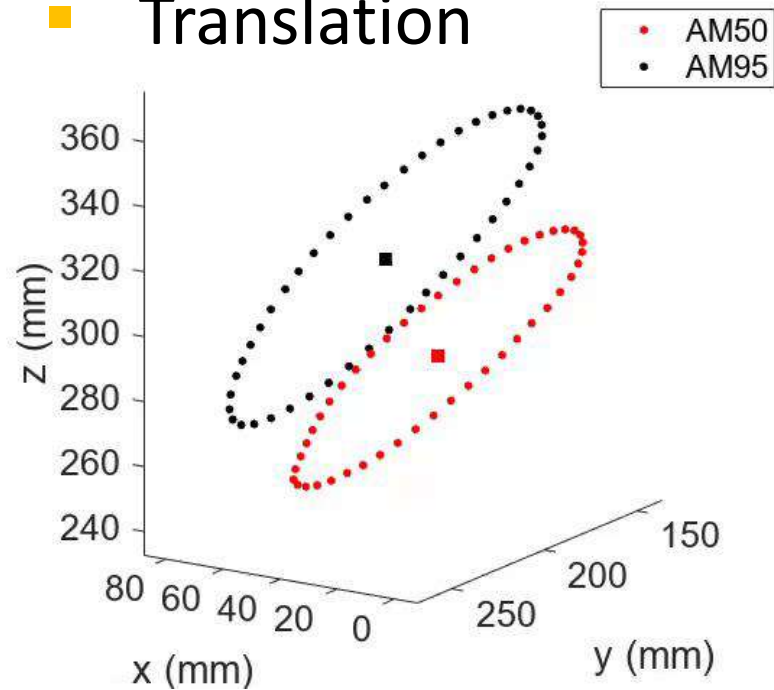
- Scaling
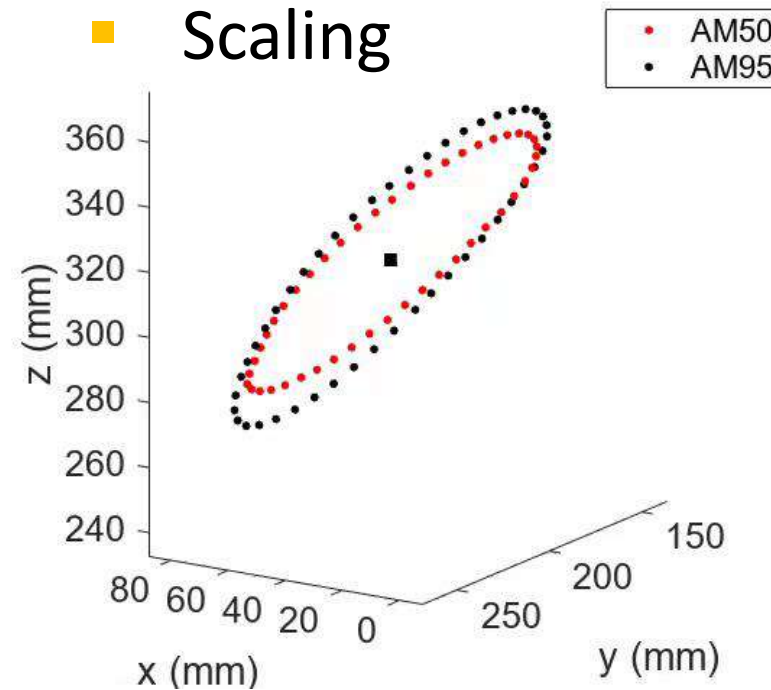
Combining the 2 operations $\longrightarrow$ Displacements: D_{50-95}

Parametric mesh morphing

- δ: modulation parameter
- D_{50-P}: source points displacement in the mesh morphing to the generic percentile

$$D_{50-P} = \delta * D_{50-95}$$

With δ varying linearly between 0 and 1 from the 50th to the 95th statistical anthropometric percentile
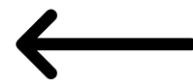
Mesh morphing implementation

Automatic procedure in 4 phases:
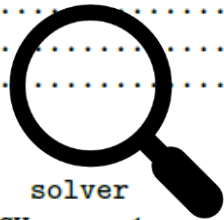
1. Setting

2. Definition

3. Esecution ⟵ **rbf**™

4. Writing

Setting

- Reading the LS-DYNA simulation K-FILE relative to THUMS AM50

Source points coordinates

Definition

Source points coordinates

Percentile

PTS-FILE

```
1522
-811.018  67.19753  -288.0066  -38.177466141229516  3.1974164850510567  -6.893923740617389  81000774  0  s  p
-807.6782 68.16429  -292.2721  -37.94366307172289   3.2650942954424296  -7.192525414021546  81000775  0  s  p
-804.5713 69.83803  -296.3405  -37.72616419255343   3.3822640773577533  -7.4773293169819155 81000776  0  s  p
...........................................................................................................
................................................. righe omesse .............................................
...........................................................................................................
109.8944  100.7405  423.7275  13.755605995039172   8.026604098779977   32.901360113398766  89589508  0  s  p
150.0275  106.0441  408.1986  18.249523776210857   8.581565927666018   32.121853233288185  89589563  0  s  p
27.22313  111.8411  378.0515  4.498461885936079    9.188156492952311   30.608554038536354  89589795  0  s  p
```

Esecution
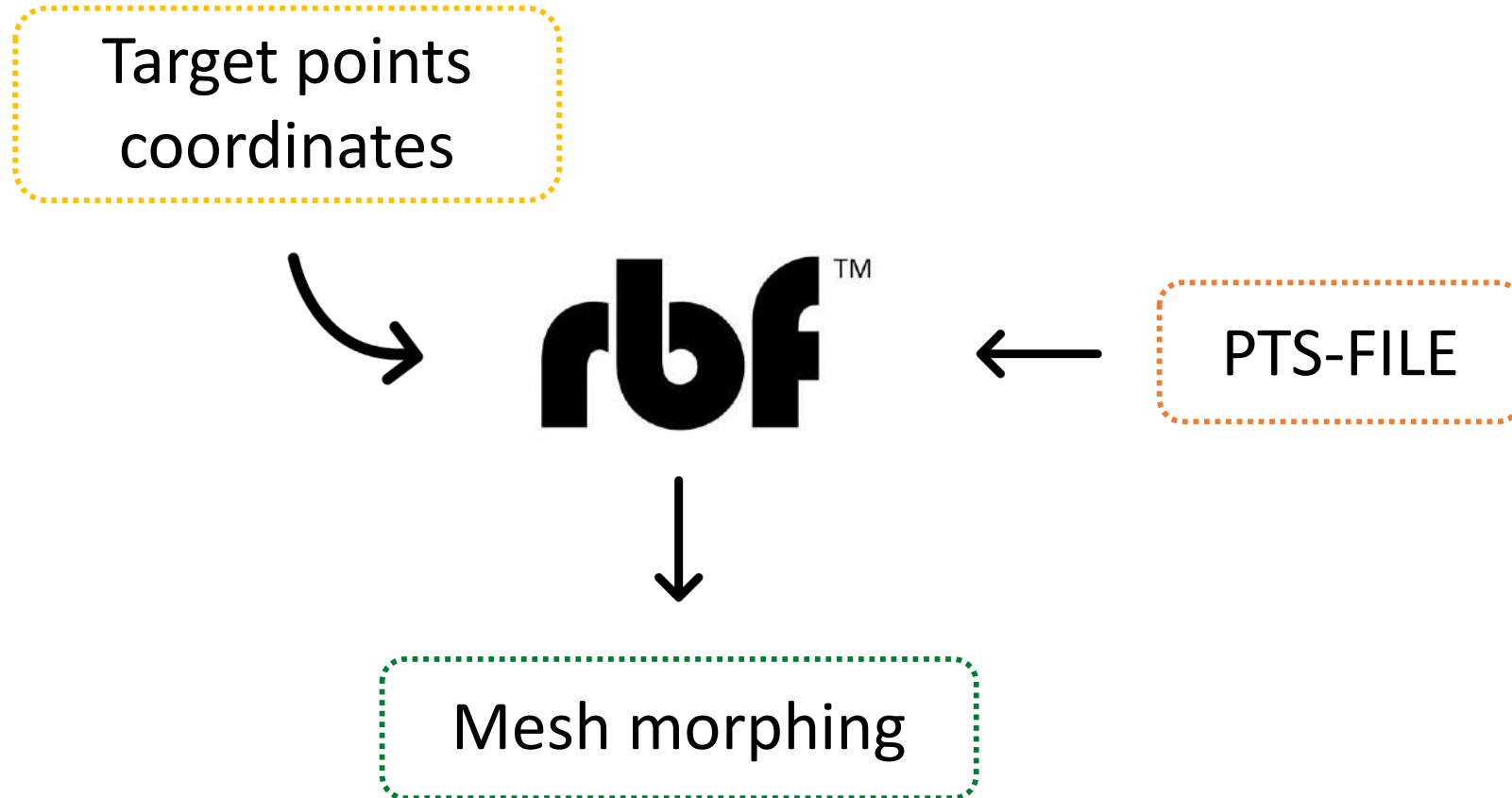
Writing

- Writing the new simulation K-FILE


```
*NODE
 7121101        132.9127         17.49752          150.8569          0        0
 7121109       -163.0202         96.61806         -48.35065          0        0
 7121152        118.2001         21.74364          156.744           0        0
 ...........................................................................
 ............................ righe omesse.................................
 ...........................................................................
```

THUMS
AM50

```
*NODE
 7121101        150.37798102      19.41371560       166.42936123      0        0
 7121109       -171.12580417     119.26328861      -44.33608968       0        0
 7121152        133.95643805      24.15646037       173.18246829      0        0
 ...........................................................................
 ............................ righe omesse.................................
 ...........................................................................
```

**THUMS
AM50mP**

Simulation

- **AM50m95:** mesh morphing to 95th percentile $\rightarrow$ 100 kg
- **AM50m75:** mesh morphing to 75th percentile $\rightarrow$ 89 kg
- **AM50m35:** mesh morphing to 35th percentile $\rightarrow$ 65 kg
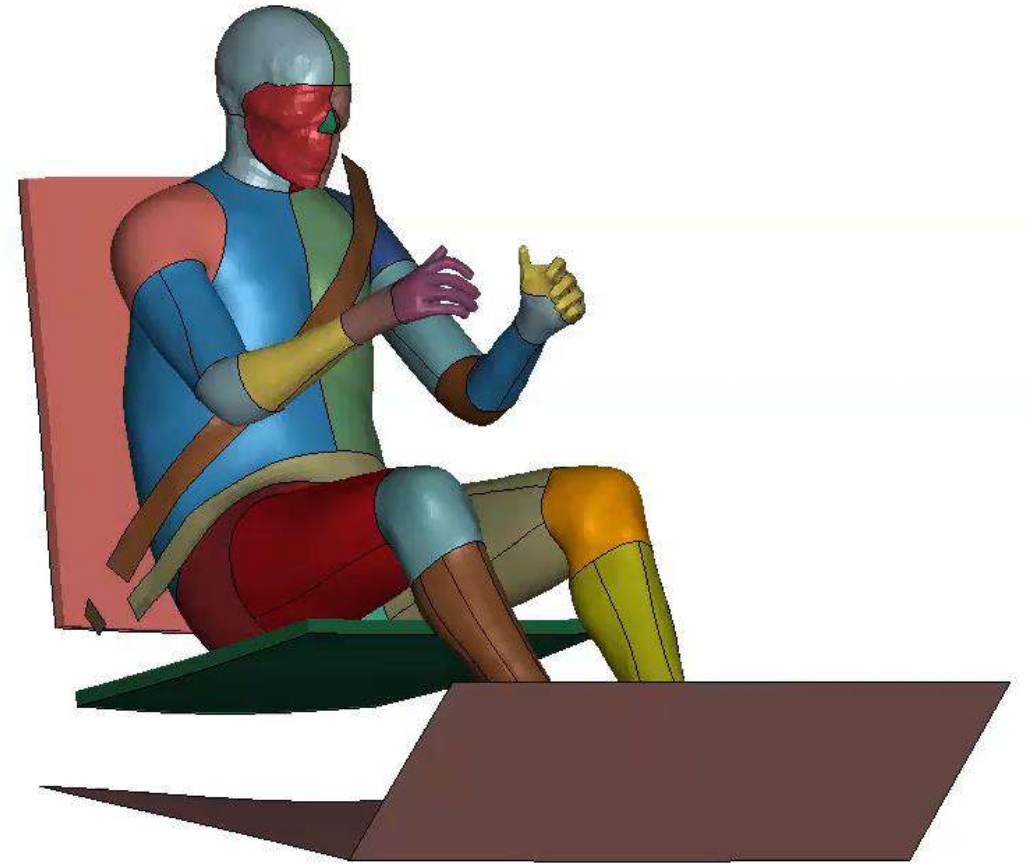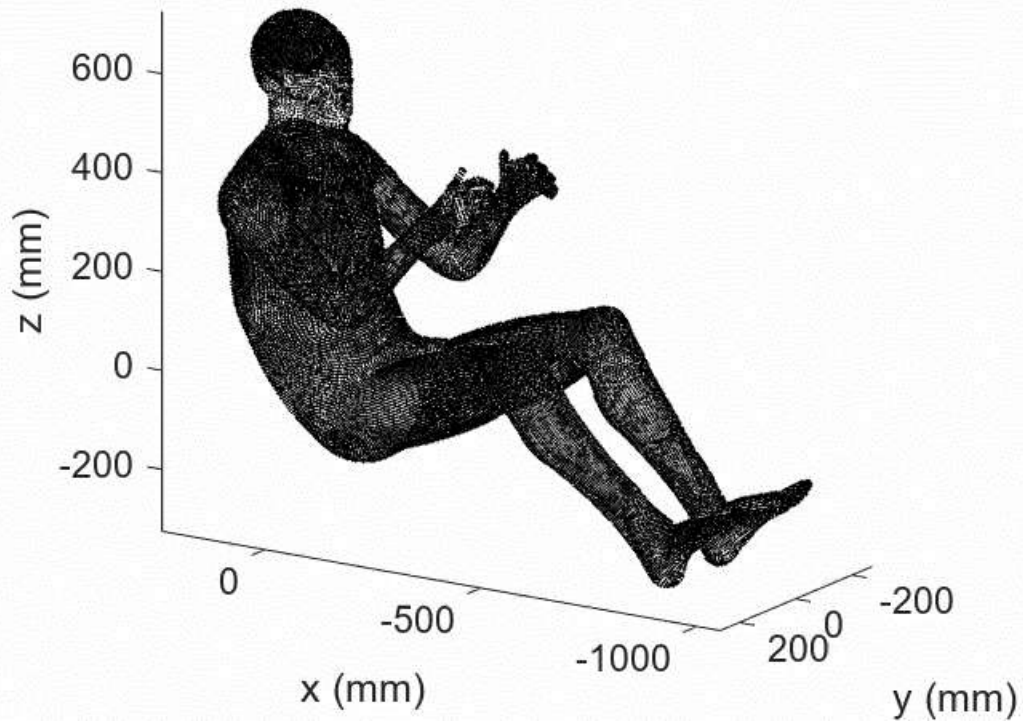

Frontal impact kinematic analysis
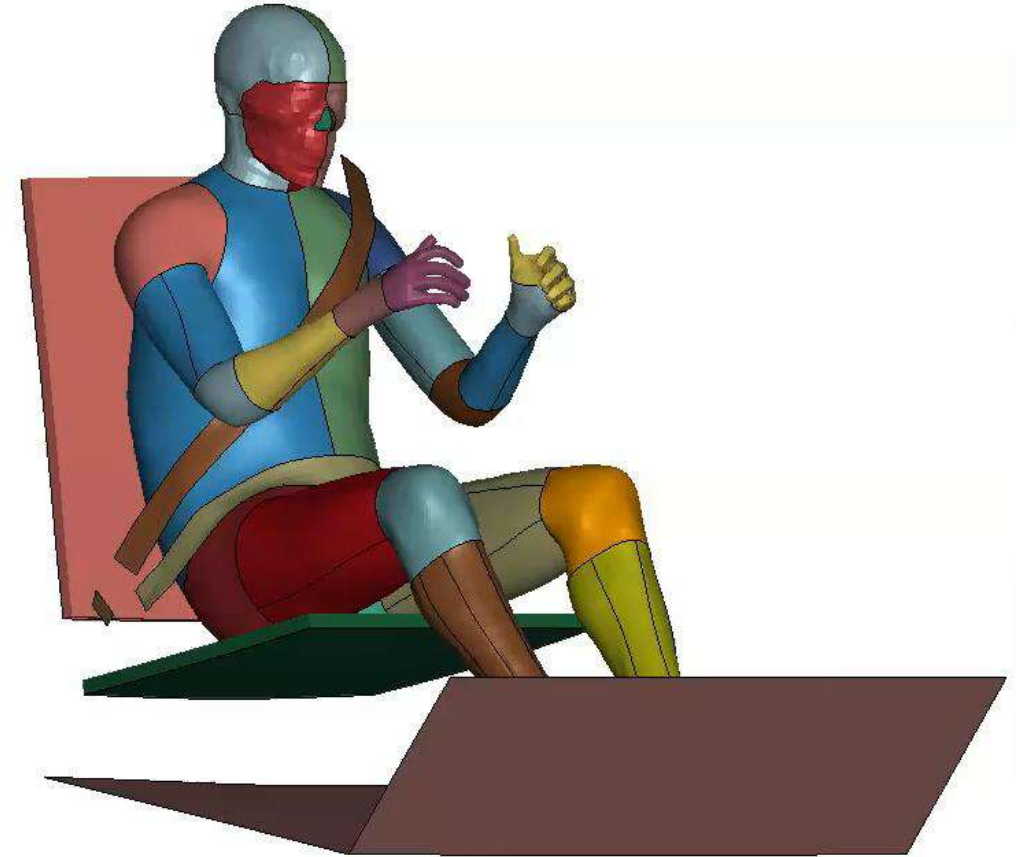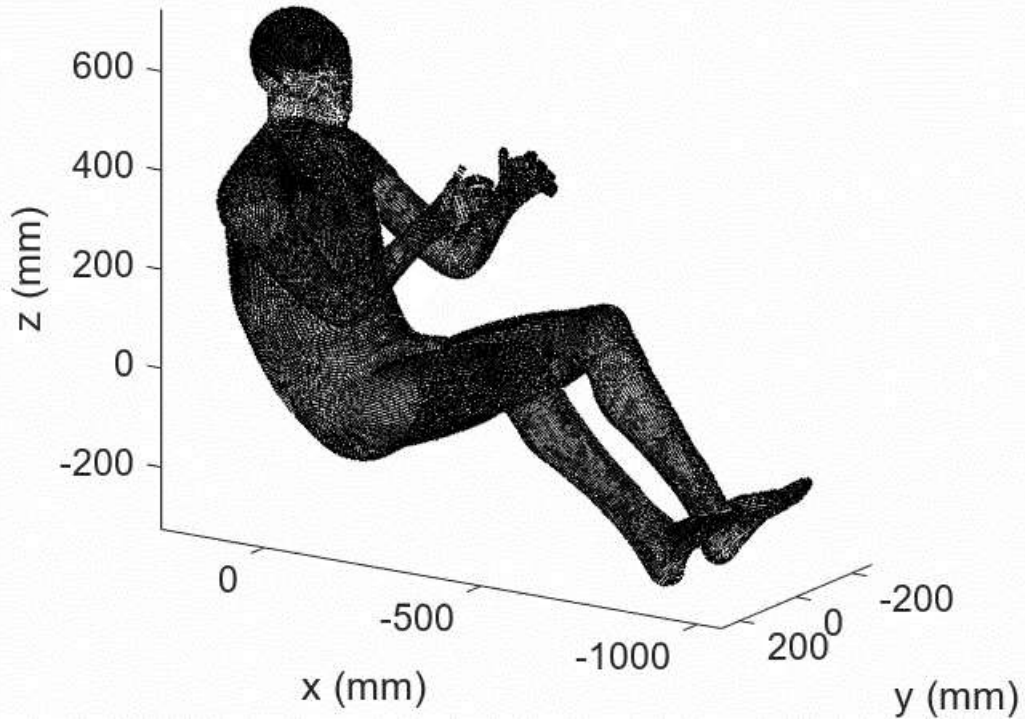
Simulation
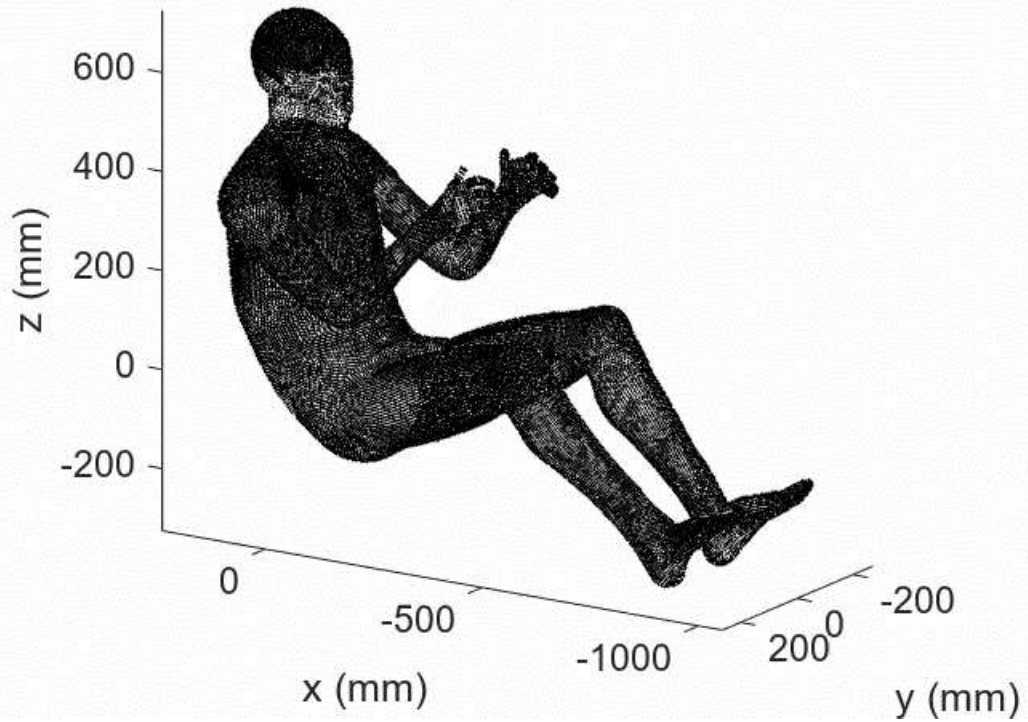

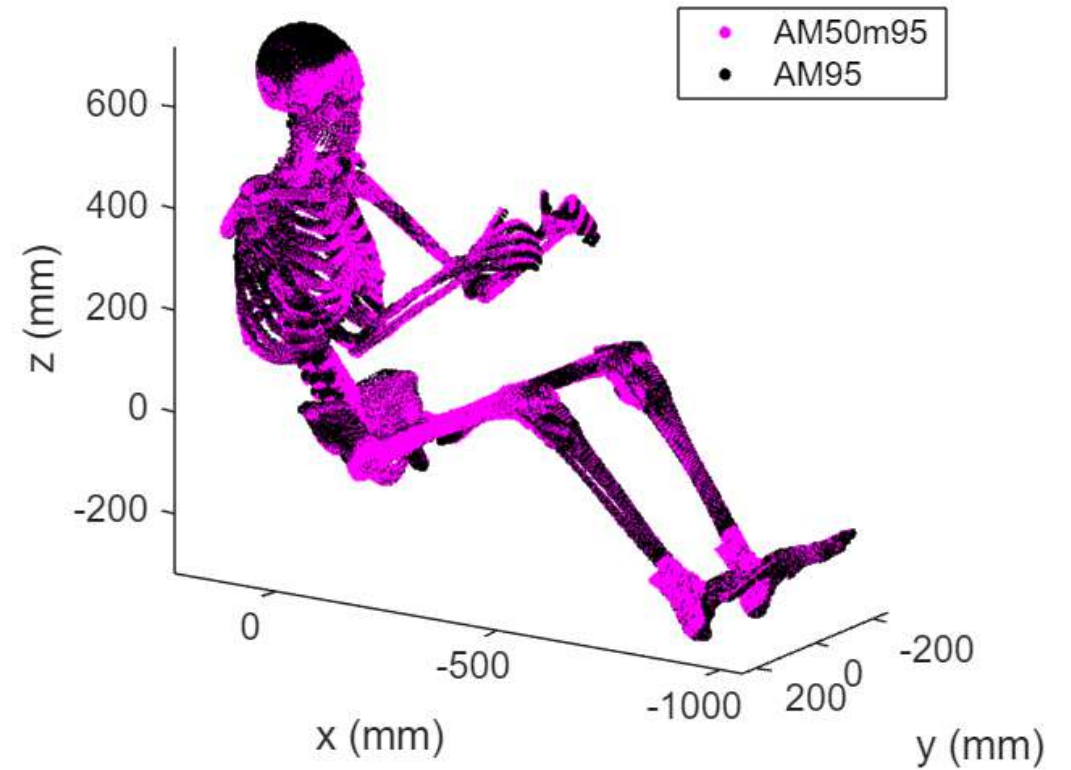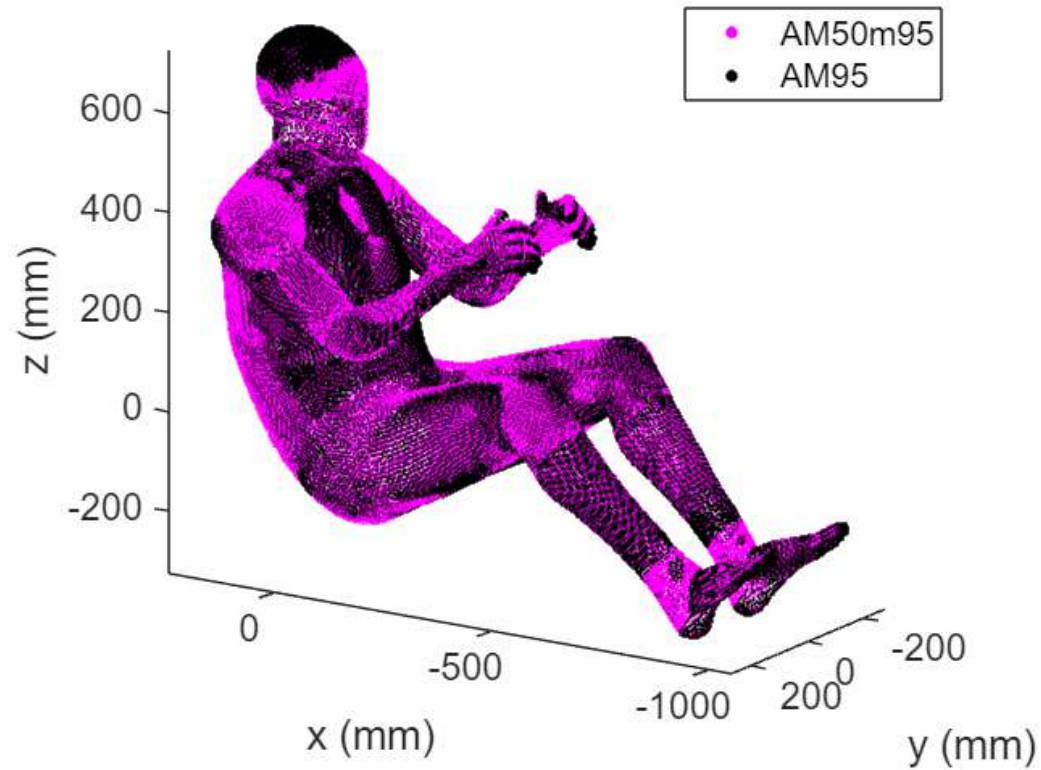
Mesh Morphing: 50° percentile

Simulation

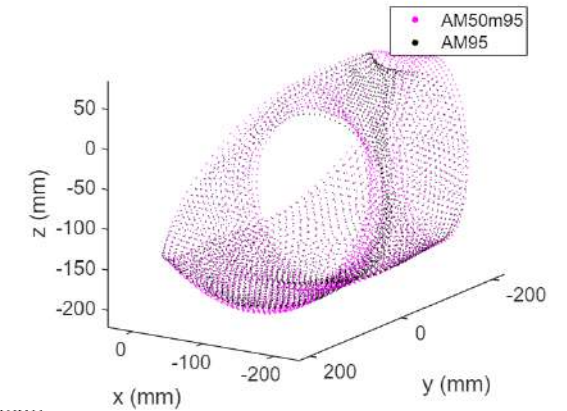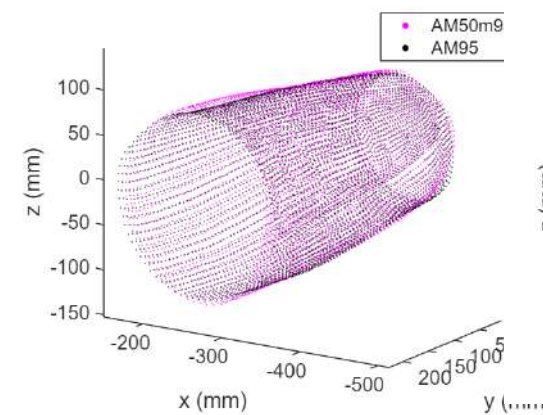Mesh Morphing: 50° percentile

Simulation
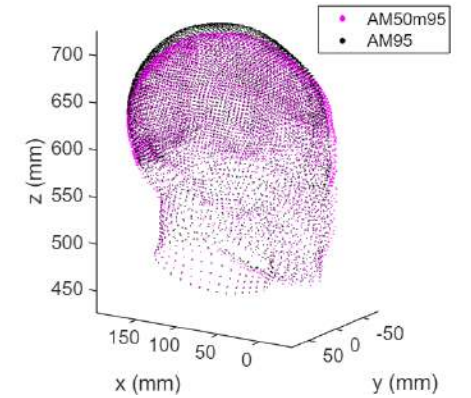

Mesh Morphing: 50° percentile

Results

- Geometry quality: AM50m95 vs AM95

Results: MDA and MDM

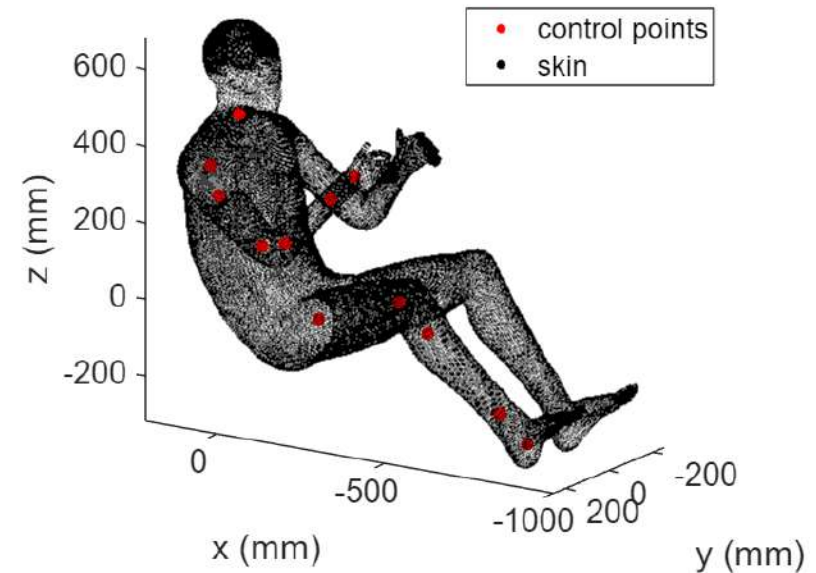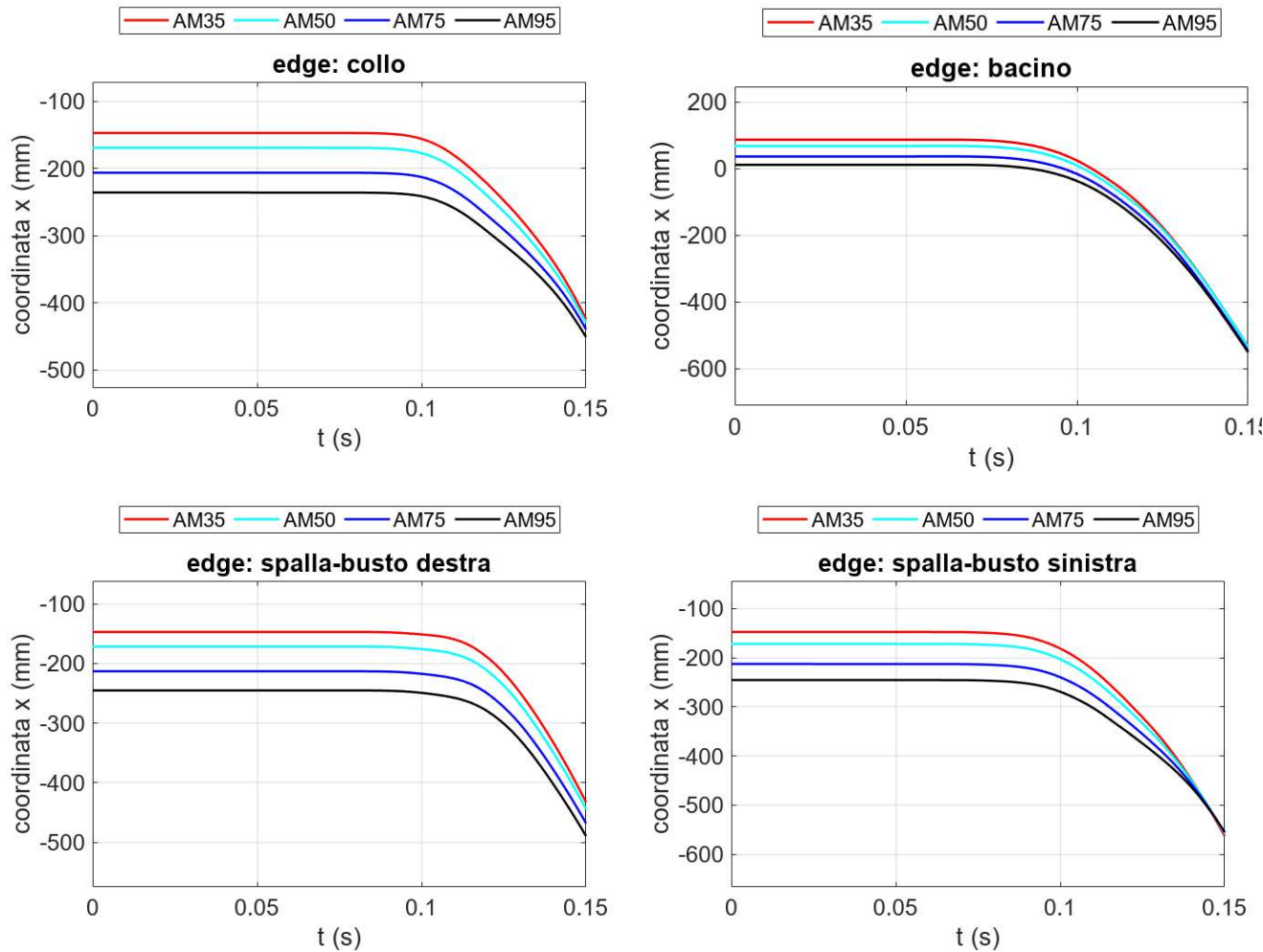| Body areas comparison			
area	**MDA [mm]**	**MDM [mm]**	**MDA/MDM**
Busto	7.10	24.36	29%
Viso	4.05	11.45	35%
Spalla	3.42	9.06	37%
...	...	...	...
Stinco	1.68	3.14	53%
Cassa toracica	1.97	6.31	31%
Ossa pelviche	2.48	7.52	32%
Average	**3.65**	**8.46**	**34%**
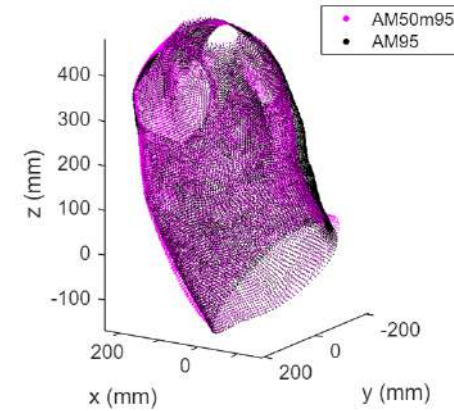
Results: kinematic analysis

- Linear influence
- Differences introduced by the mesh morphing **0.8 mm/percentile**

Results: kinematic analysis

S_{mean} related to the AM95 [mm]		
Control points	**AM50**	**AM50m95**
Bacino	55.89	8.57
Collo	54.71	6.67
Busto-spalla destra	61.72	9.87
Busto-spalla sinistra	58.36	4.34
...	...	...
Stinco-caviglia destra	17.31	13.91
Stinco-caviglia sinistra	17.84	14.70
Piede destra	18.97	19.62
Piede sinistra	18.99	19.62
Average	**34.42**	**7.84**
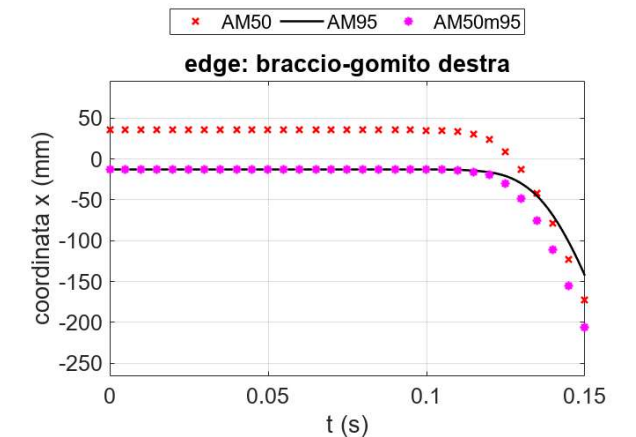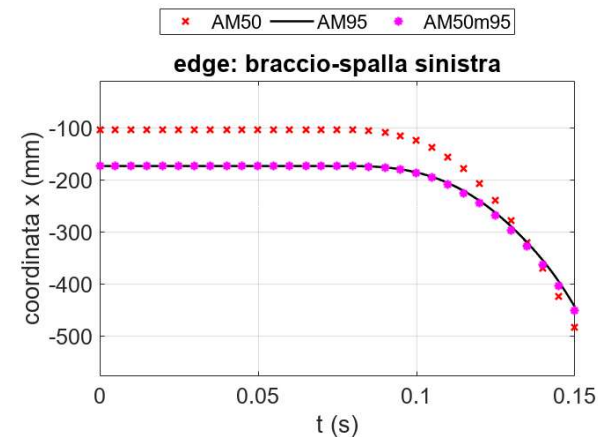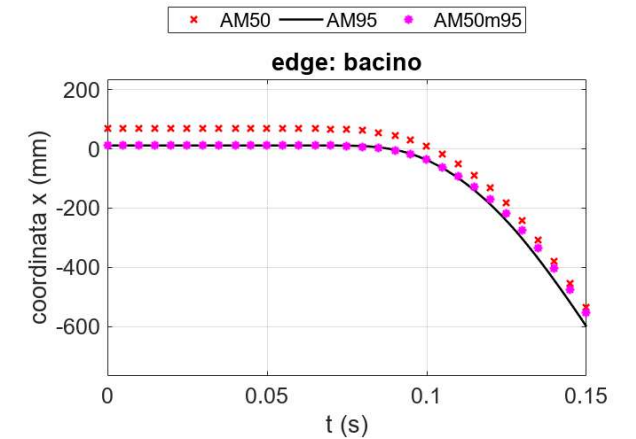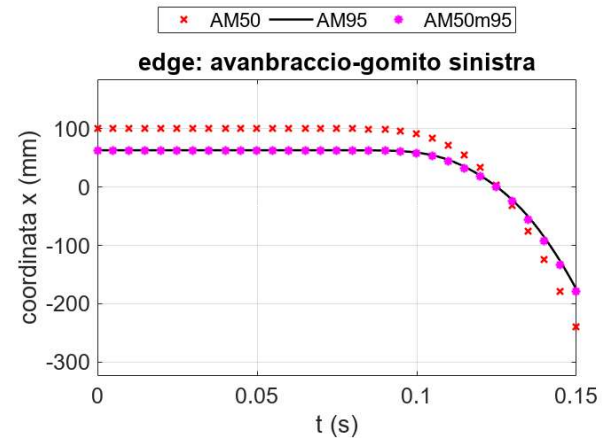
Conclusion

- Method

- Method efficiency

- Choices effectiveness

Thanks for your attention