Development of an Open Source Framework to position and personalize Human Body Models

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Background and motivation

Human Body Models: performance increasing …

++ stable, approaching all known PMHS responses (better than dummies…),

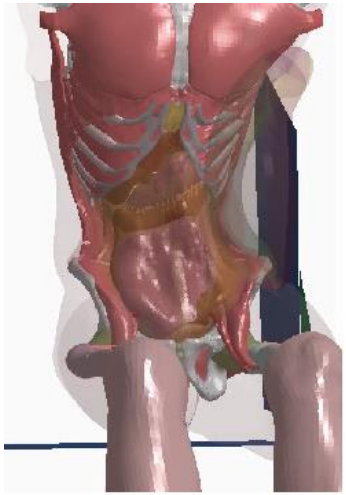
++ a few families available

-- same sizes as dummies

-- Typically one posture only = daily use difficult (vehicle, research, OOP, precrash…)

-- not always easy to access (does not help for specifications, reproducibility, procedures…)

Thums (source: Toyota Newsroo



GHBMC (source: LBMC)

PIPER Project (Nov 2013 - Apr 2017)

- Objectives: methods and tools position and personalize HBM Child model (PIPER child model, 1.5-6YO) ➔ Open Source

FP7 European Project, 3.8M€, 10 partners

FE modeling for impact

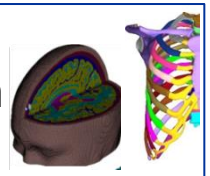
Academics

Hip positioning

FITT

Subject & population specific modeling

CEESAR
KTH
UCBL
TUB



Other fields

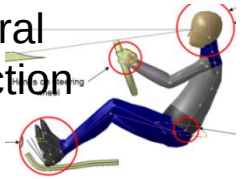
Academics

Femur statistical modeling

SOTON

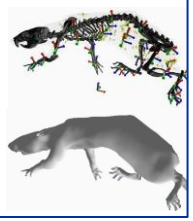
Postural prediction

UCBL



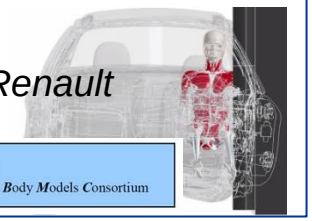
Realtime Postural change

INRIA



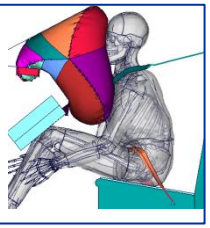
Industry

LAB
Peugeot Renault



GHBMC
Global Human Body Models Consortium

PDB
Partnership
Dummy Tech.
and Biomech



Specs & apps (WP1)

Aim: user specs + doc, eval, improve child models

Predictors of posture & shape (WP2)

Aim: use *a priori* knowledge (posture, shape) ➔ target

P&P methods & tools (WP3)

Aim: transform HBM (num)

PIPER software: A Modular Framework

- FE HBM I/O
- Project Save/Open
- Modules that can update data (history/undo)
- Interactive GUI (+batch mode)
- Model visualization

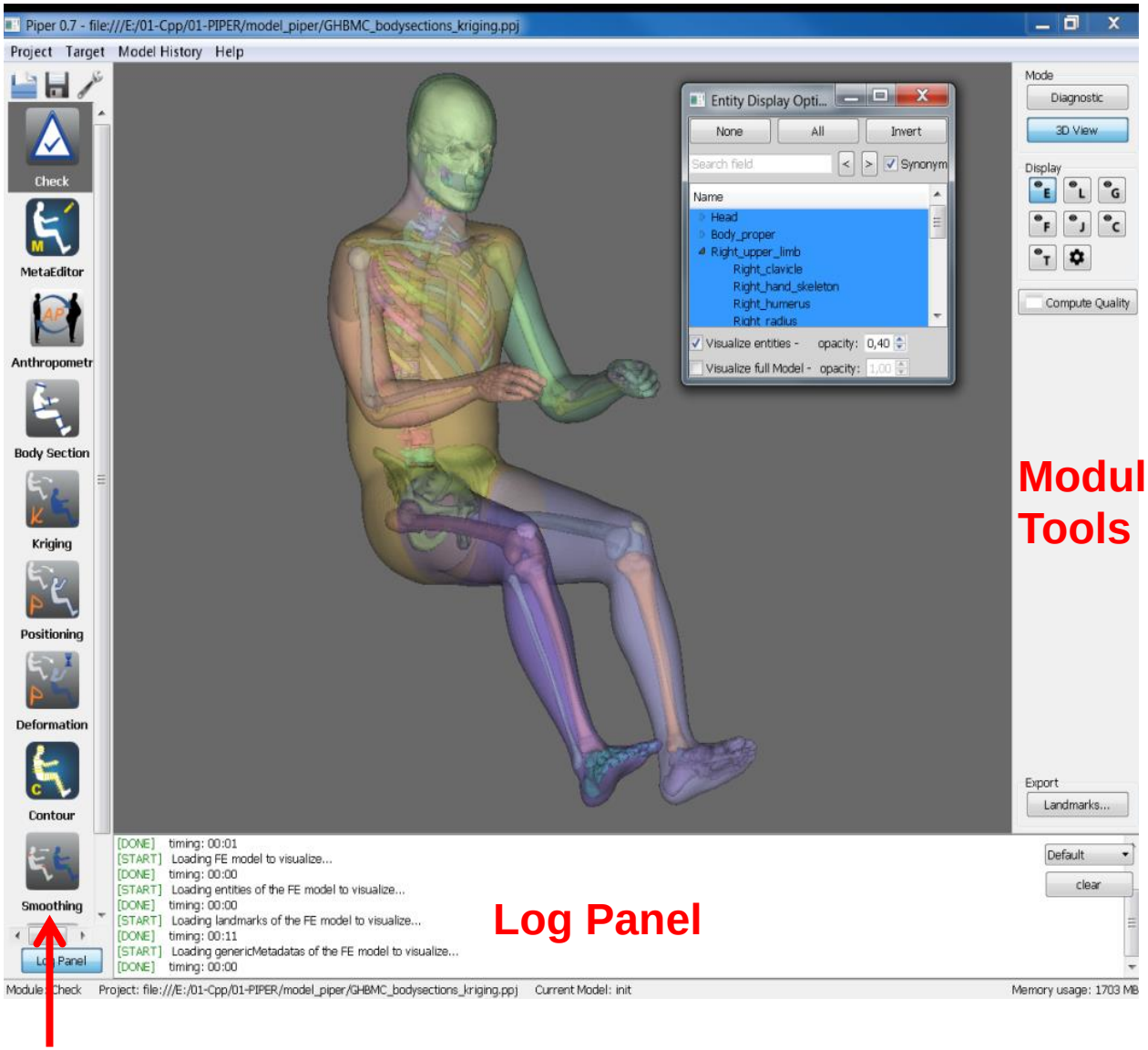
Windows / Linux

VTK Qt CMake

SOFA Simulation Open Framework Architecture GNU Octave

TetGen, Mesquite

…



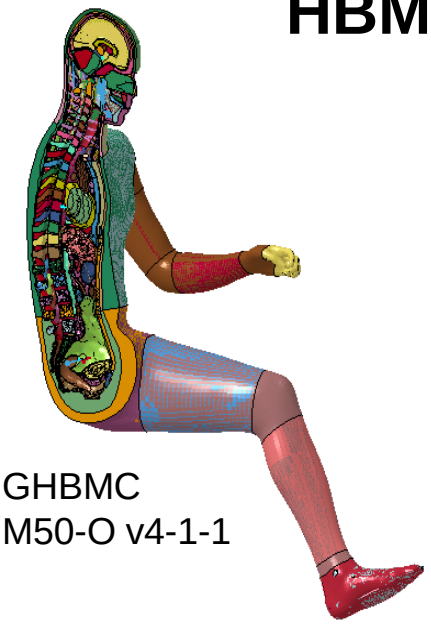
Module Tools

Log Panel

Module Selection

PIPER Framework: I/O - Import FE HBM

HBM



GHBMC
M50-O v4-1-1

\+

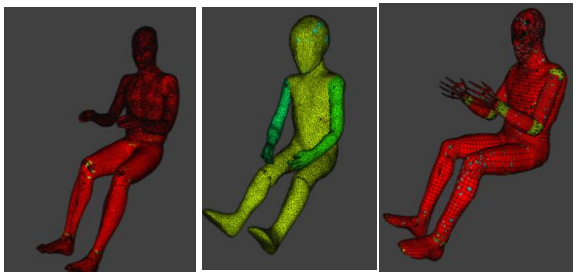
User defined Metadata & parsing rules

- Anatomical components
- Joints
- Rigid
- …

=

User:
1) defines FE groups using standard pre-processing software to describe anatomical entities, landmarks, contacts ➔ **FE Format**
2) associates groups and anatomical entities (AnatomyDB), joints, contacts ➔ **XML file**
3) selects rules to parse FE format input ➔ **XML File** (provided, can be modified to add features or code)

➔ Used so far: GHBMC (Dyna/Pam), Thums, Piper Child model, (Viva)



Workflow example: scaling based on anthropometry

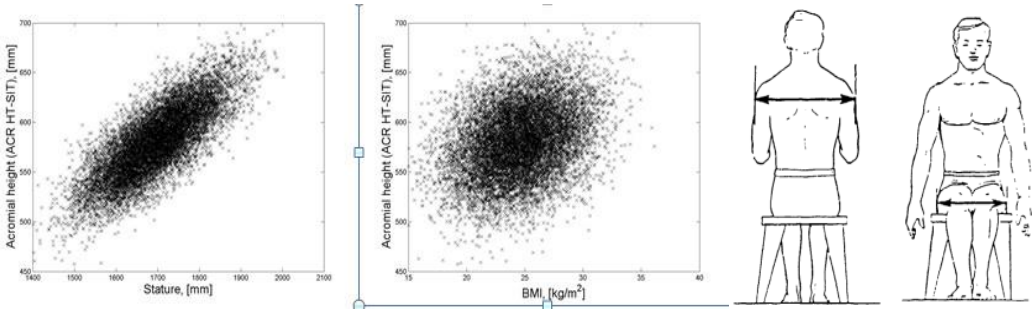
1 – Definition of target body dimensions: Anthropometry Module

Anthropometry module

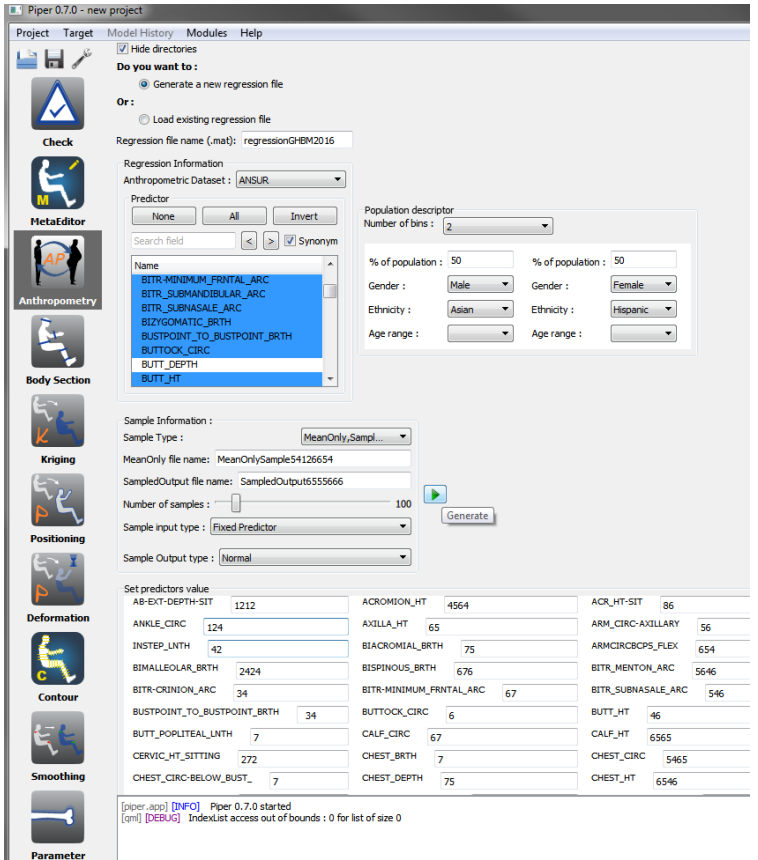
Uses existing DB (adult: ANSUR, Child: “Snyder”…) to predict dimensions

Free choice of predictors (stature, gender, dimension …)

Virtual population to compensate limited data *(Parkinson et al. 2009)*



Provide full of set of anthropometric dimension targets



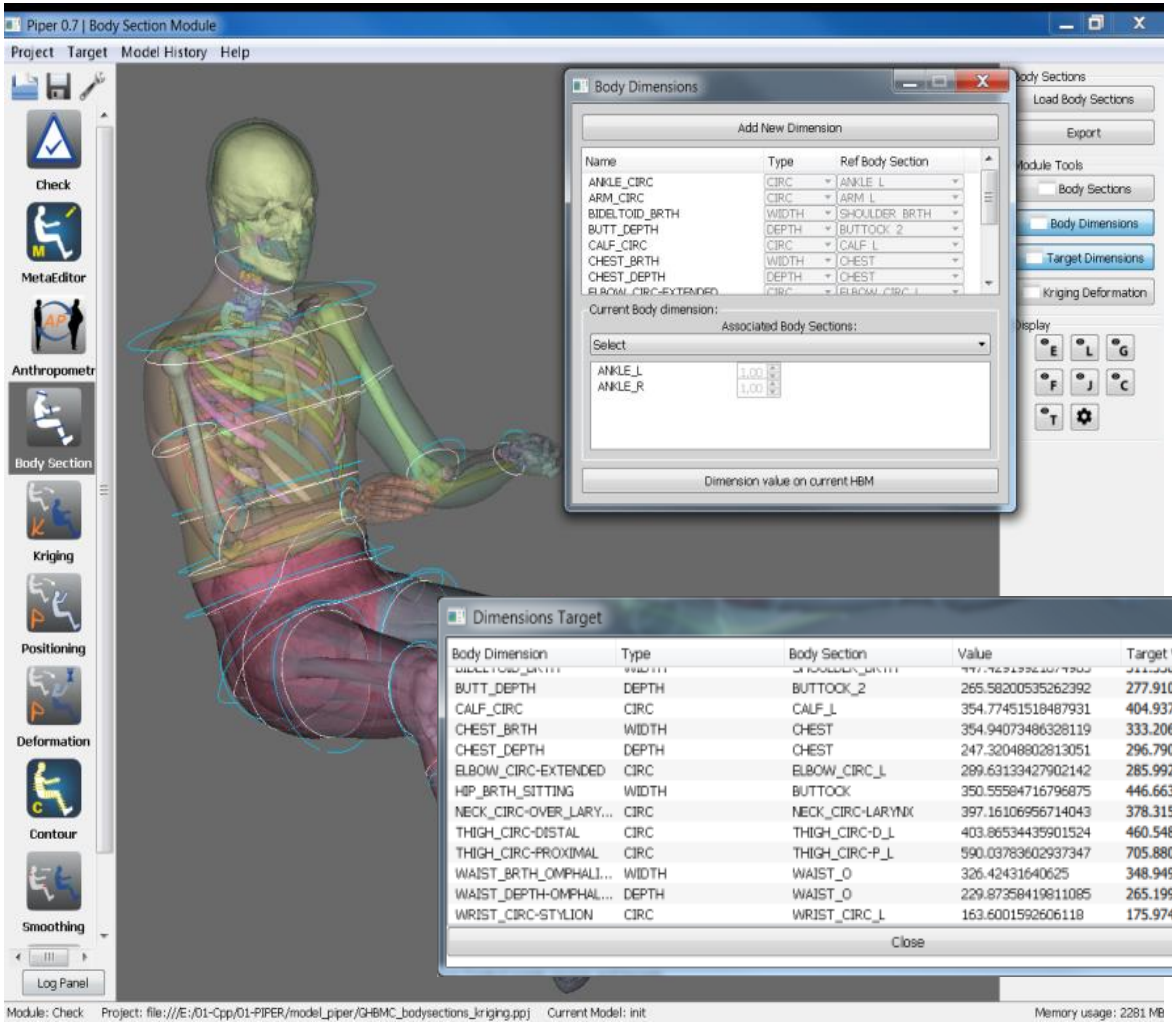
Workflow example: scaling based on anthropometry

1 – Definition of target body dimensions

2 – Describe body dimensions on the HBM: Body Section Module

Body section module

- Link anthro to HBM dimensions
- Generates control points



Workflow example: scaling based on anthropometry

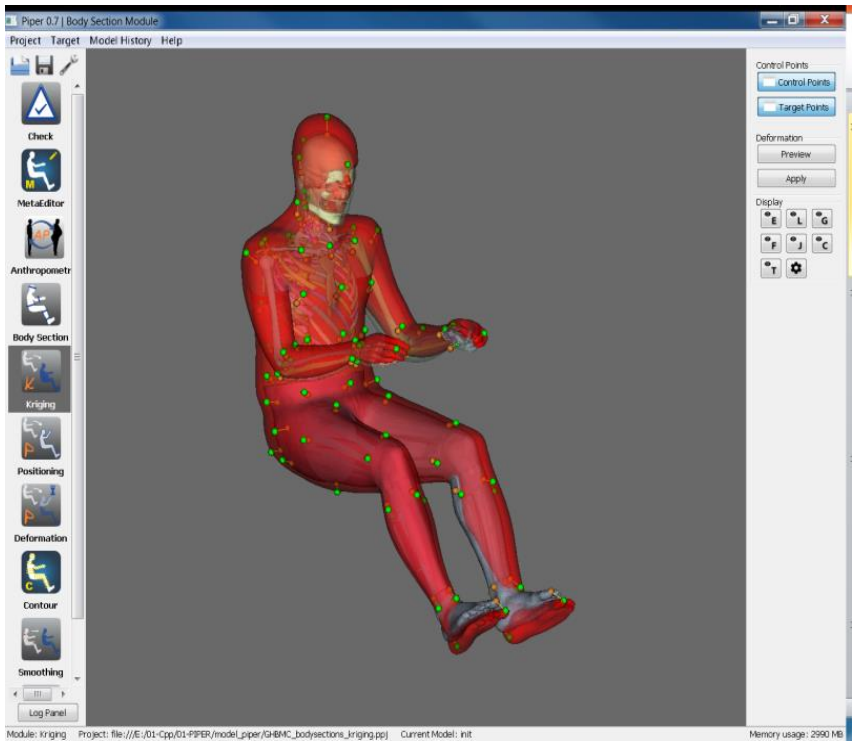
1 – Definition of target body dimensions

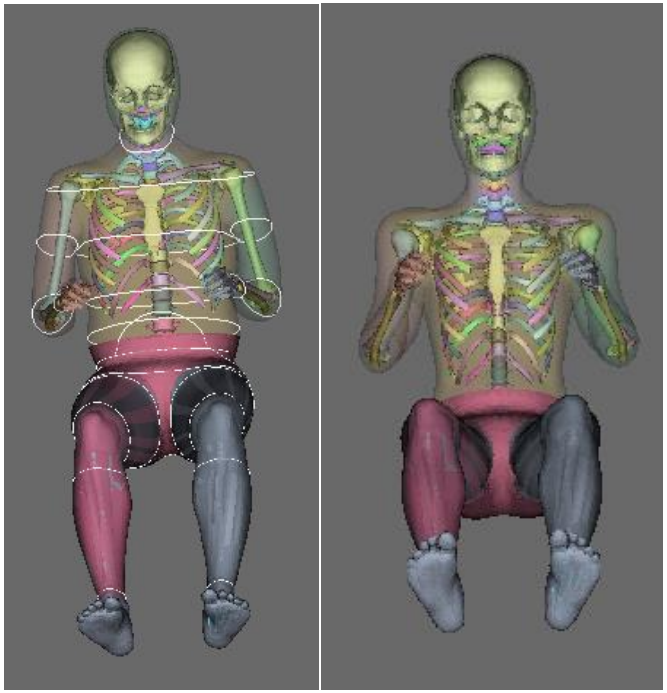
2 – Describe body dimensions on the HBM

3 – Deform the model: Kriging module

4 – (optional) apply other modules (ex: change parameter defined in metadata such as material properties) , post process (smoothing, …)

Kriging module

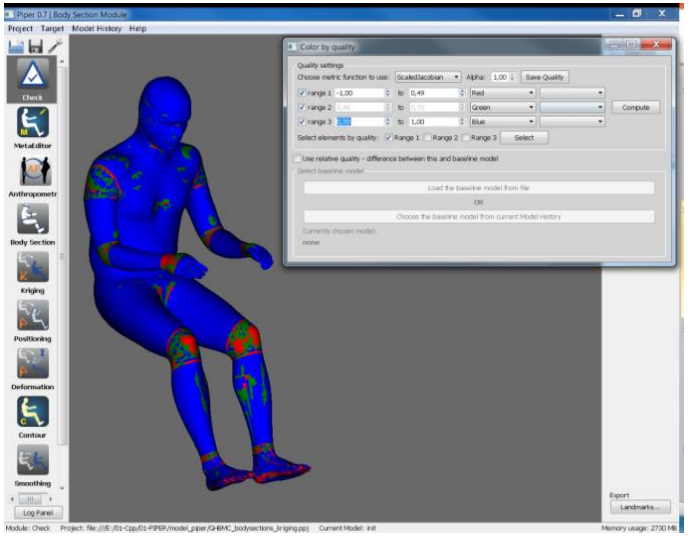




Post processing tools

Mesh Quality Metrics:

Calculation and display incl. relative quality (between / after…)



Mesh Quality Optimizer:

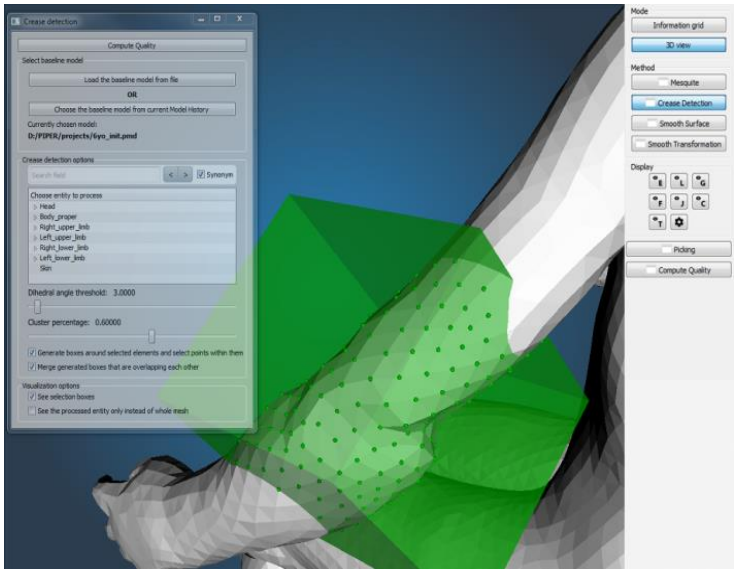
Optimize locally element quality (using MESQUITE Toolkit)

Transformation smoothing module:

Smooth (/edit) surface, regional smoother of transformation (between surface constraints)

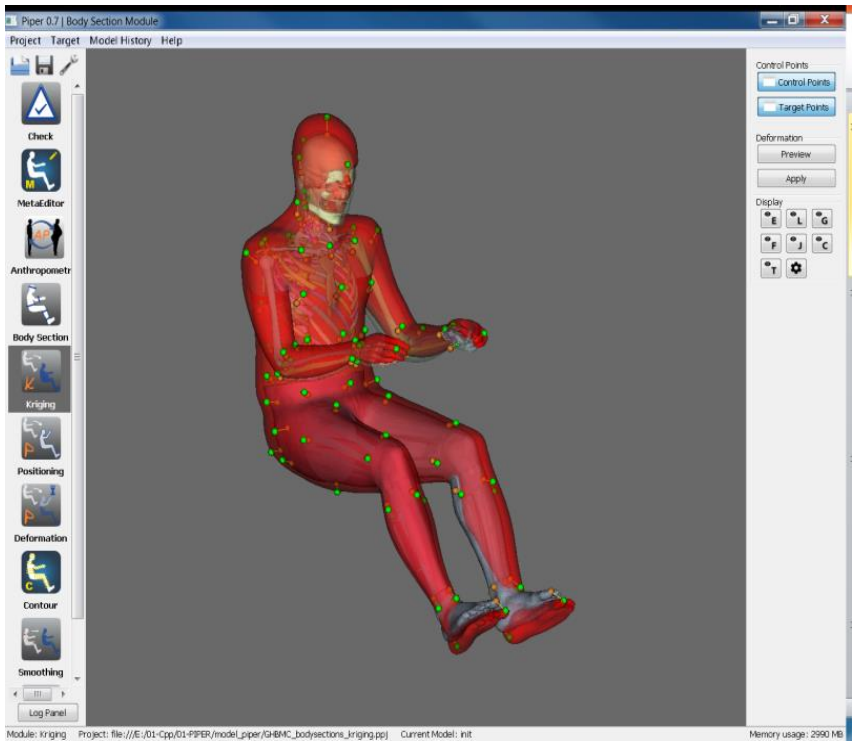
Aims: maintain quality, (typically) respect contacts

Applicable to any workflow



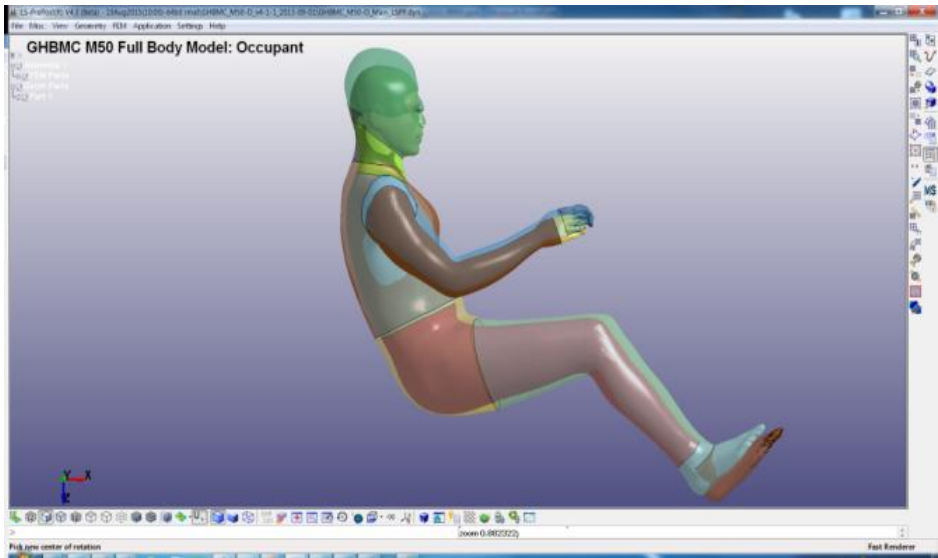
Workflow example: scaling based on anthropometry

1 – Definition of target body dimensions
2 – Describe body dimensions on the HBM
3 – Deform the model
4 – (optional) apply other modules (ex: smoothing, change parameter defined in metadata such as material properties) …
5 – Export



Export

Updated and Baseline FE models

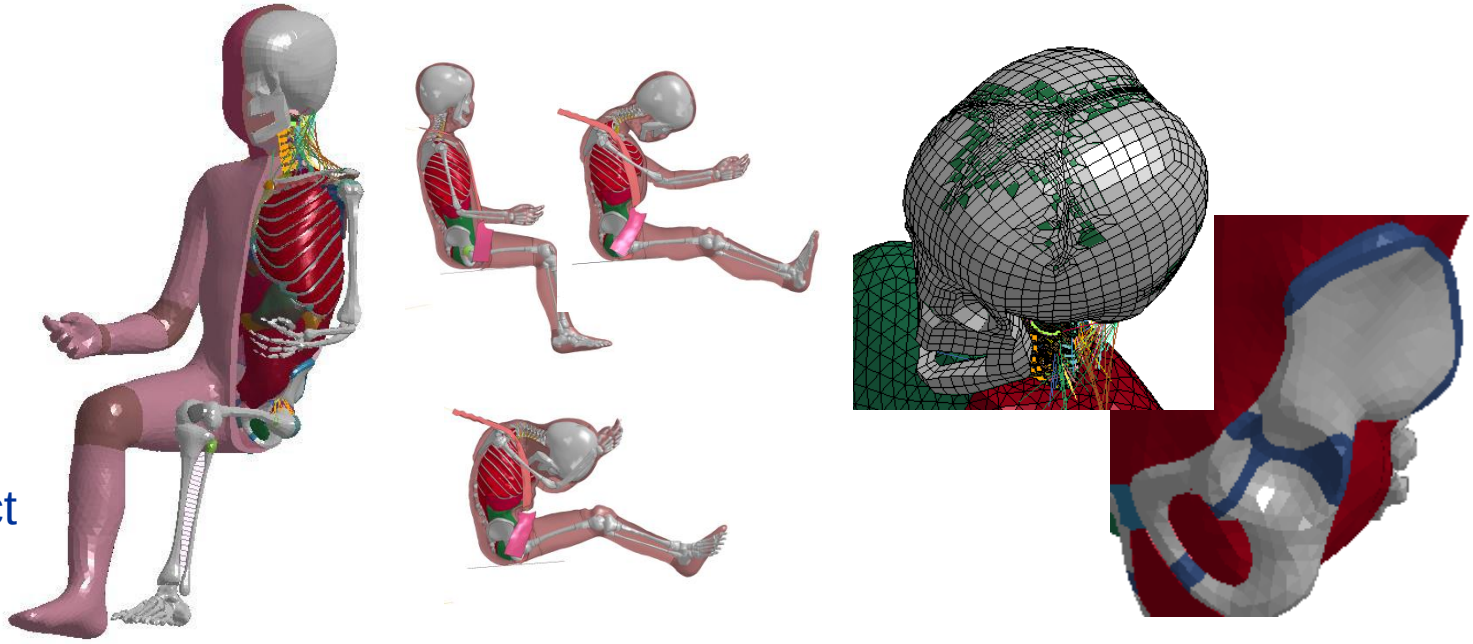


Summary/status: scaling / personalization

- **Based on anthropometry**
  - Modules available ➔ need to refine, integrate more workflows, etc… (e.g. length in body section, more skeletal constraints)
    - Methodology already defined and tested
- **(ongoing) PIPER child model dedicated workflow**
  - Age vs. Anthro, local geom, some material (growth cartilage, brain)
  - Note: use of external/user Octave/Matlab scripts possible…

PIPER Child
~500k elements
1.5-6YO
(here: 6YO)

Regional
Global kinematics
Frontal, Side impact



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- **(ongoing) PIPER child model dedicated workflow**
  - Age vs. Anthro, local geom, some material (cartilage, brain)
  - Note: use of external/user Octave/Matlab scripts possible…
- **(Missing) Based on statistical Shape Models of full skeleton:**
  - Still missing…but hoping to have it at the end…
- **Other schemes are possible… but time is short**

Workflow example: Positioning

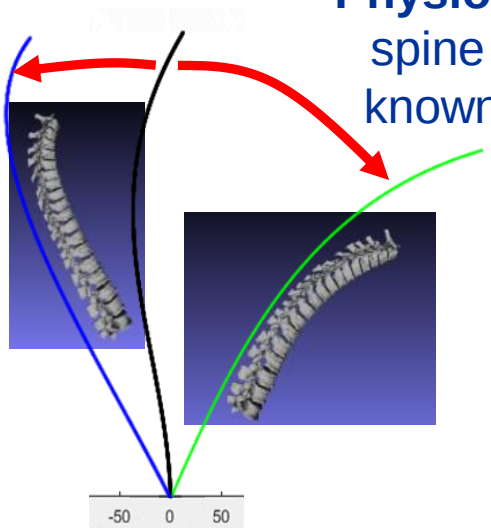
1 – Define the target position: Interactive Positioning Module

- lightweight physics model automatically create (HBM + Metadata).
- Includes functional constraints: bone collision, sliding contacts, joints…

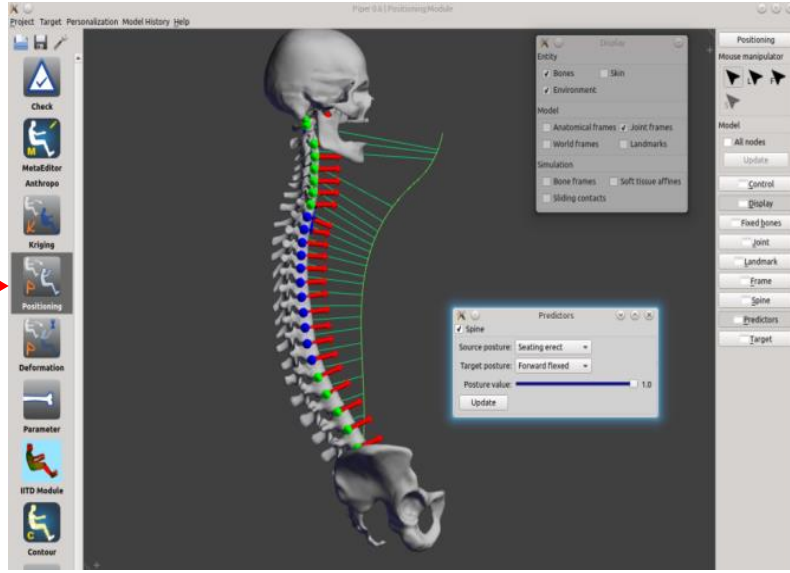
+ User constraints: fixed bone, joint angle, bone landmark position…

+ *A priori* (biomech, ergo…) constraints to increase realism of target

➔ (real time) simulation to compute posture



Physiological prediction of spine cuvature, based on known postures, and user targets



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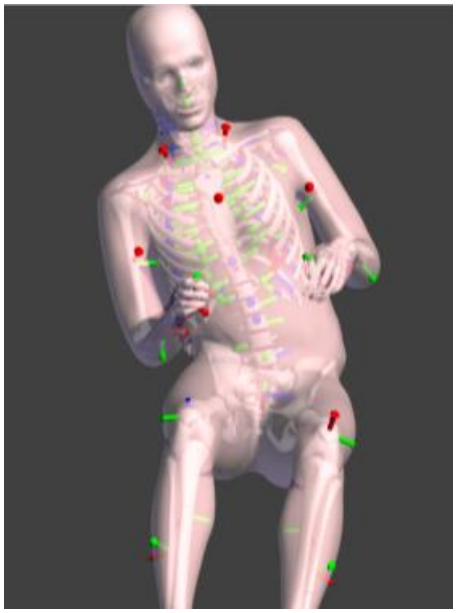
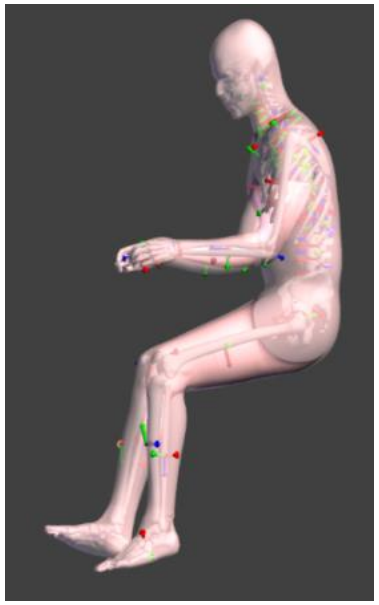
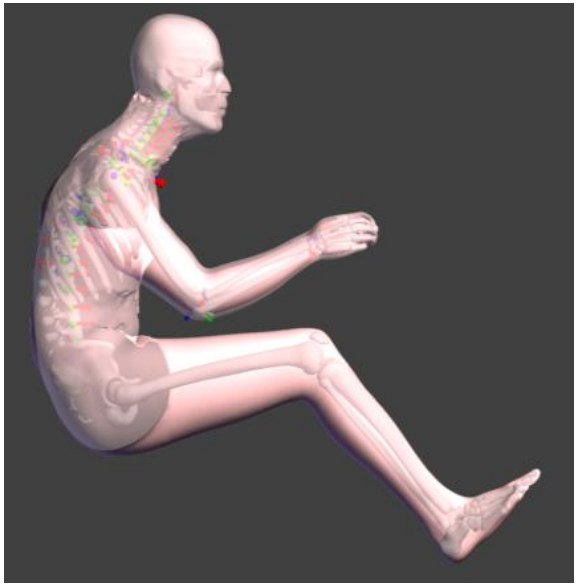
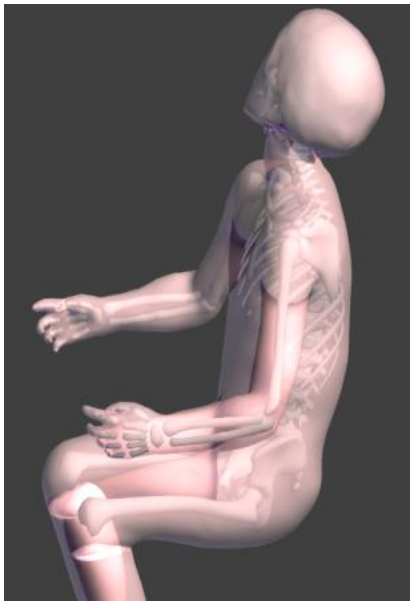





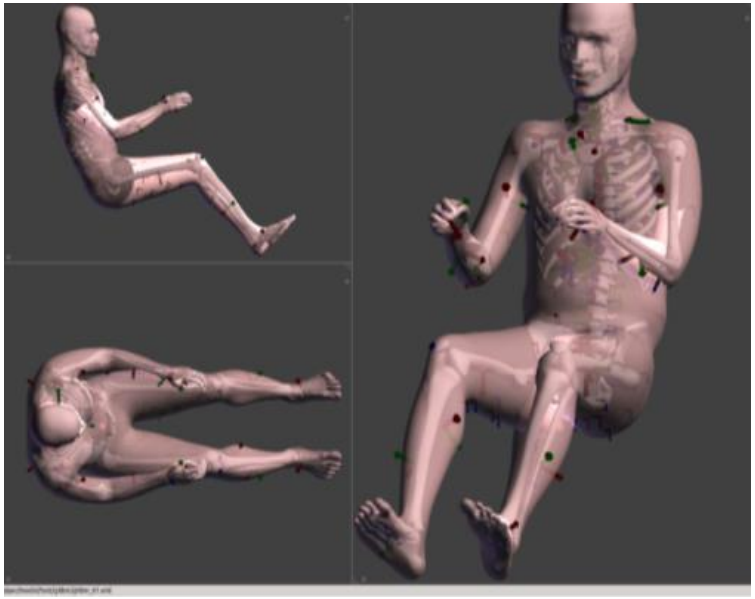
Workflow example: Positioning

1 – Define the target position

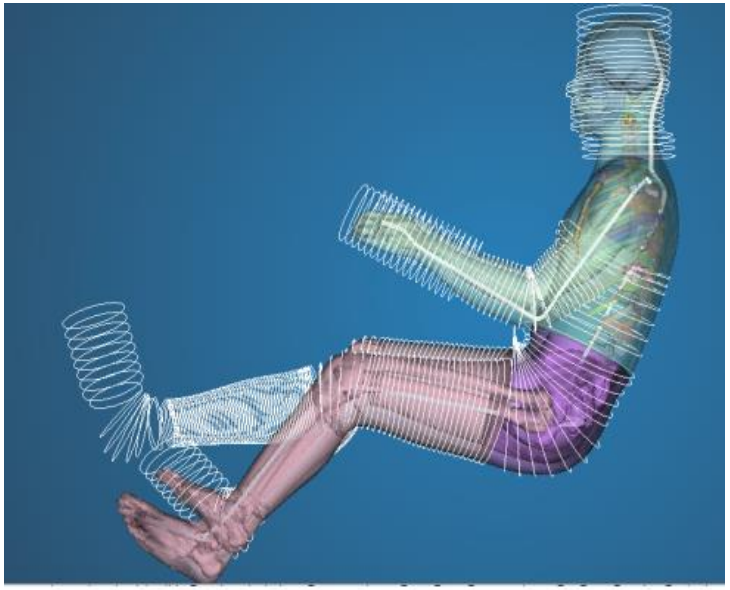
2 – Deform the model: two approaches available inside PIPER

+ possible to use simulation workflow (updated model or landmarks used as simulation target) ➔ automation ongoing

Physics-based Transformation[1]:



Contours-based Transformation[2]:



[1] B. Gilles, et al. Frame-based interactive simulation of complex deformable objects, 2013
[2] D. Jani et al., Repositioning the knee joint in human body FE models using a graphics based technique, 2012.

Workflow example: Positioning

1 – Define the target position:
2 – Deform the model
3 – Improve regional mesh quality: smoothing
4 – Update FE model

Before Positioning

After Positioning

Summary/status: Positioning

- Applied to different models
- Fully successful (=directly runnable output model) on sagittal movement. Range of motion is of course an important parameter…
- **Limitations**: Still working on improving the lightweight physics simulation (soft contacts, transformation…), contours, debugging/robustness, a priori knowledge integration, integration with simulation workflow

Reminders:

- Large range of motion likely to affect mesh deformation/quality independently of the deformation method used
- HBM design can limit their usability for positioning (continuous mesh, lack of sliding component bones/soft tissues…)

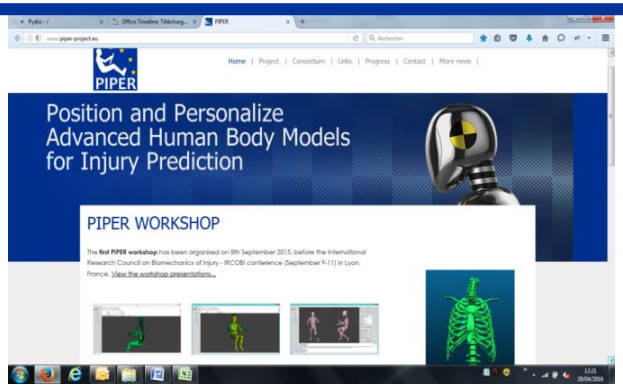
Conclusions

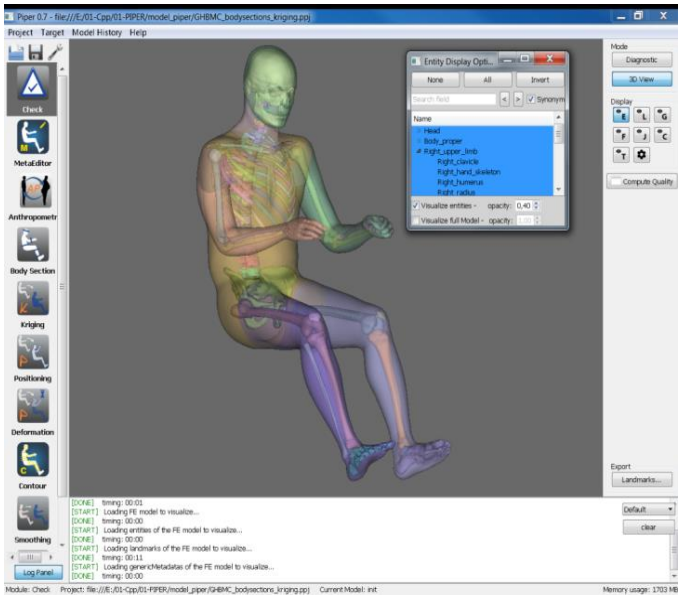
- Novel (unique) framework for P&P, using modular approach
  - FE code and model independent
  - Accounts for actual workflow (industries & acad users)
  - OPEN. Methods/data (yours?) can be added
- Beta version of software ready (import/export, modules…)
  - Workflows being developed / used for applications
- External beta testing: starting soon (short timeline, NDA)
  - Aim: gaps user expectation vs. functionalities, stability, priorities
- Perspectives
  - Add more modules (a priori, …), bug fix, feedback …
  - Public release: April 2017… (workshop in Paris). License:
    - Software: GPL v2 or later ;
    - Child model: GPLv3 + Open Science clause
    - Metadata: talks model providers
  - Open Source management structures: maintenance, …

Thank you

Release: April 2017
Final Workshop in Paris

http://www.piper-project.eu/





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Overall approach and project structure