



## PIPER: Open source software to position and personalize Human Body models for crash applications

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6<sup>th</sup> International Symposium:  
“Human Modeling and Simulation in Automotive Engineering”  
October 20 - 21, 2016

## PIPER: Background and motivation

Human Body Models: performance and sophistication are increasing but still seldom used:

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

++ a few families available

-- same sizes as dummies  $\neq$  population variability

→ Methodologies (scaling) needed to increase coverage based on a family baselines

-- Increasingly complex to develop (expertise, funding, academic & business models?)

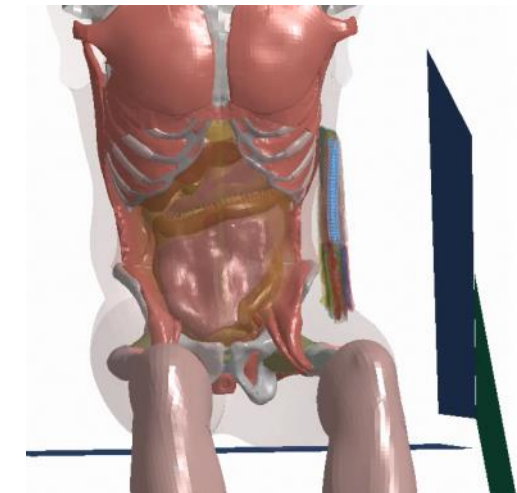
-- Typically one posture only = daily use difficult (vehicle, research, OOP, precrash...)

→ need for positioning methodologies

-- Model availability not enough to ensure wide use: specifications, certification, reproducibility, procedures, virtual testing?



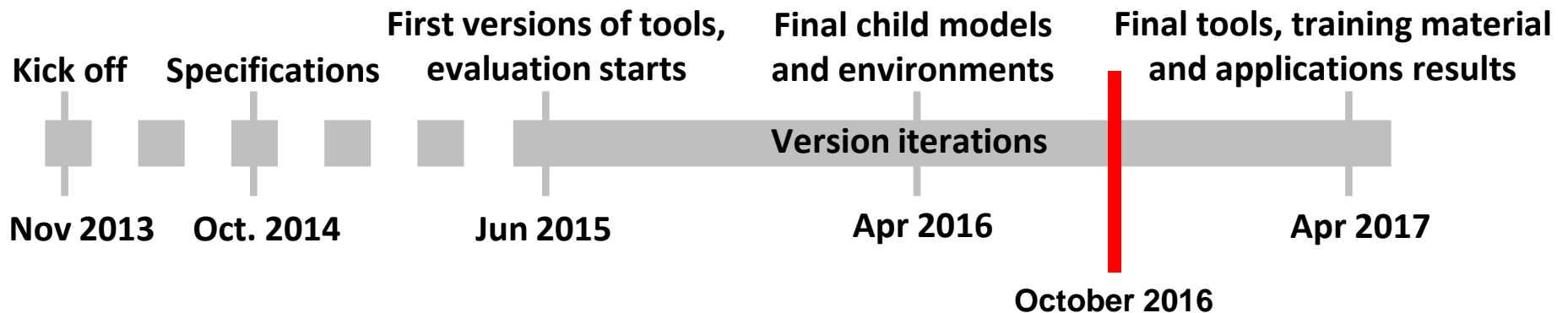
Thums (source: Toyota Newsroom)



GHBMC (source: LBMC)

## PIPER: Project & objectives

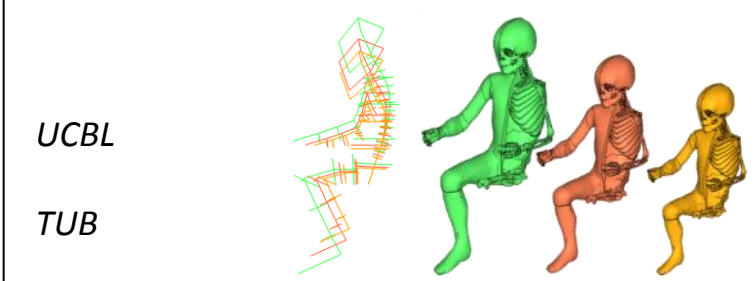
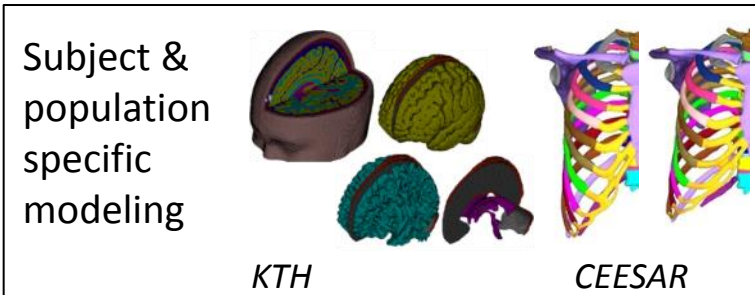
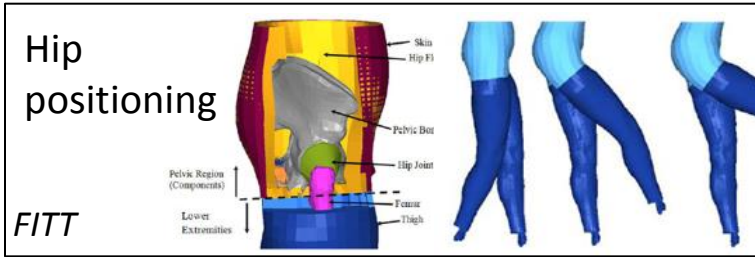
- Possible ways forward:
  - Work on generic methods to position and personalize models
  - Change IP model to secure access to tools & models for all, encourage costs sharing
    - Limit dissipation, facilitate future common procedures
- Collaborative project: PIPER (FP7 European Project)
  - 10 partners, Budget: 3.8M€, 2.9M€ funded
  - 42 months (Nov. 1st 2013, Apr. 30, 2017)
- Objectives
  - Open Source tools to position and personalize HBM
  - Open Source Improved child models (child baseline)



# PIPER: Partners

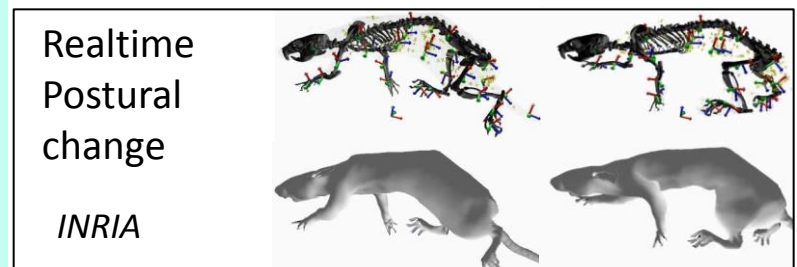
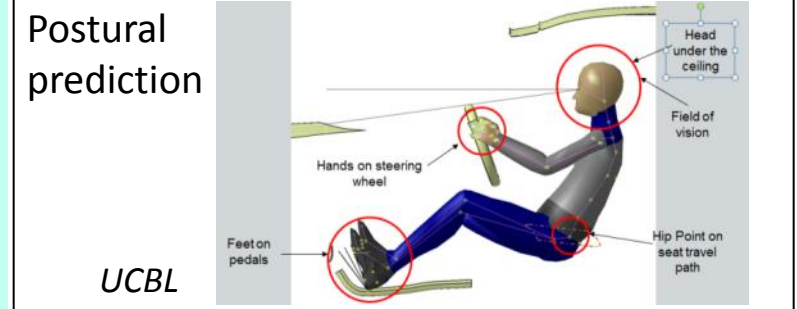
FE modeling for impact

Academics

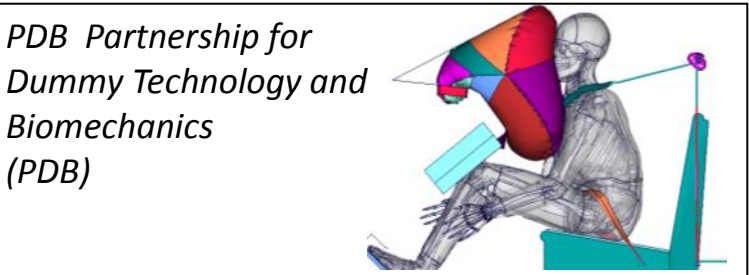
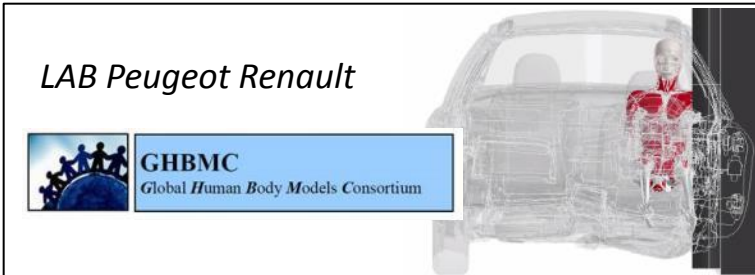


Other fields

Academics



Industry



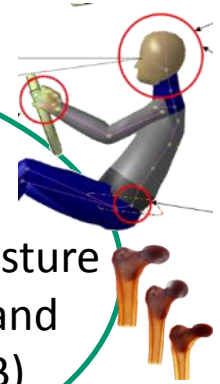
# PIPER: Overall approach and project structure

## WP1: Specs & apps

Aim: define specs from user viewpoint and evaluate the tools in real applications; Improve child models

## WP2: Predictors of posture and shape

Aim: use a priori knowledge on posture and shape to guide positioning and geometrical changes (tools+DB)



## WP3: P&P methods and tools

Aim: transform full FE models to describe other postures and populations (tools)

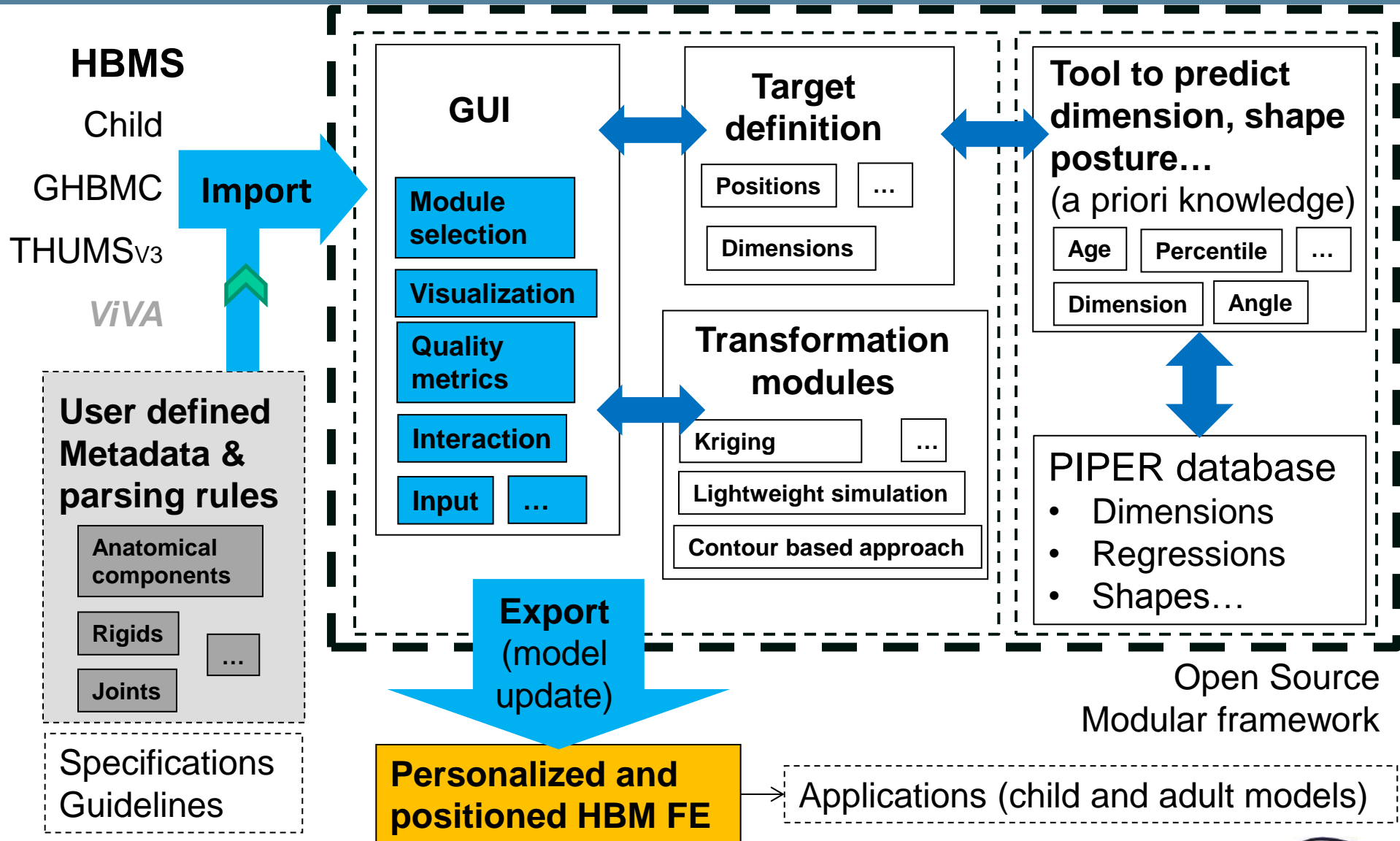


## WP4: Dissemination

Wide distribution, Open Source tools

## WP5: Management

# PIPER: Overall approach and project structure



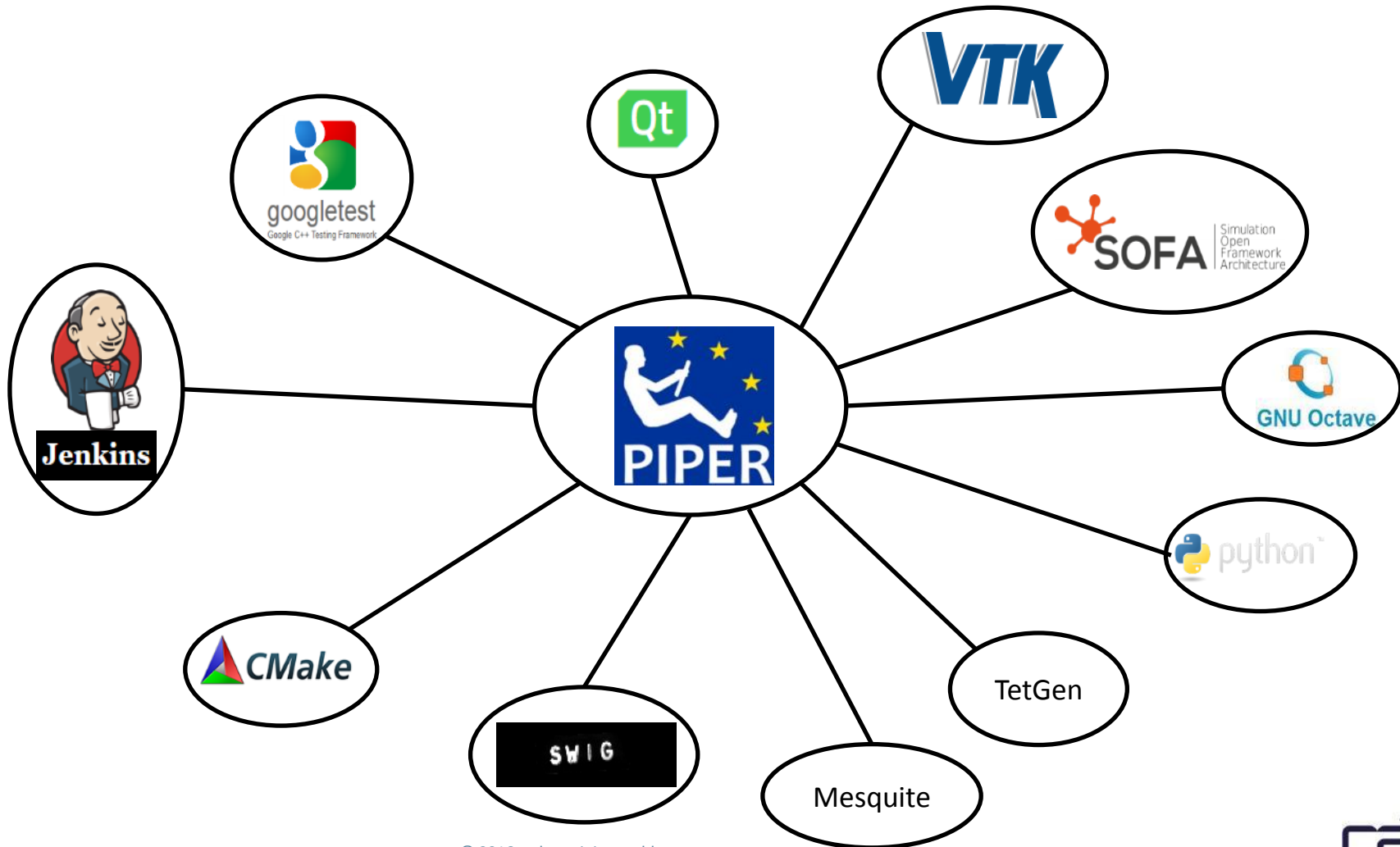


# PIPER: Open source software to position and personalize Human Body models for crash applications

## Framework

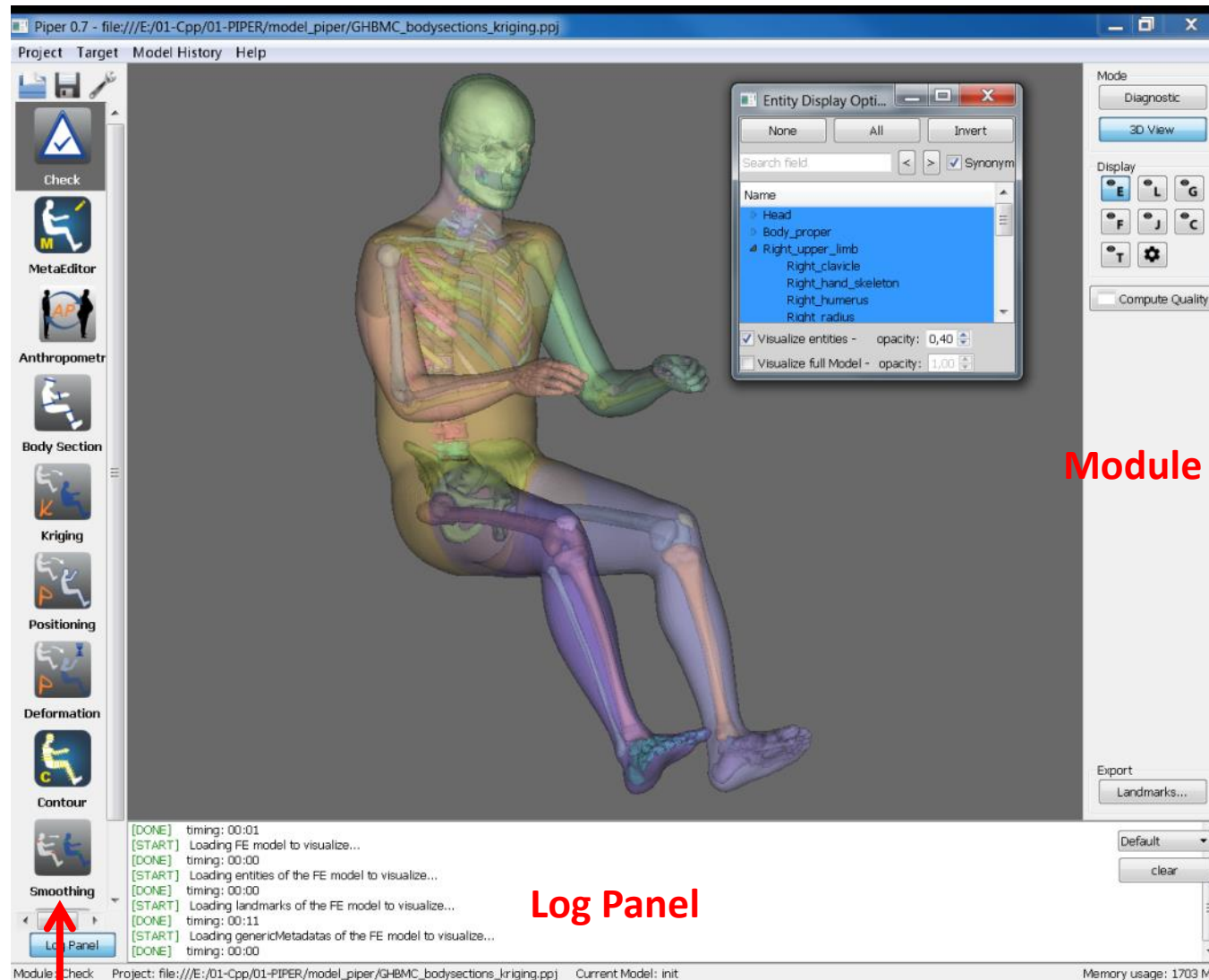
# PIPER:

**PIPER tools license: GPL v2 or Later**





# PIPER: Framework



- FE HBM I/O
- Open/save PIPER project
- Model visualization
- Check module

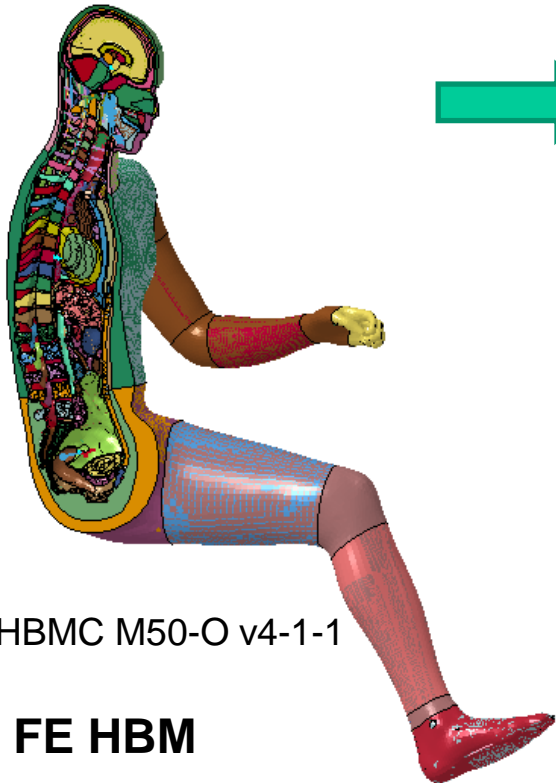
**Module Tools**

**Log Panel**

**Module Selection**

# PIPER: Framework

## Import FE HBM



## Prepared FE HBM

User defines additional FE groups using standard pre-processing software:

Group of elements: anatomical entities

Group of nodes:

- Landmarks
- Contact region between two anatomical entities



## Metadata

User defines association between:

Group of elements  $\Leftrightarrow$  Anat. Entities

Group of nodes  $\Leftrightarrow$  Landmarks

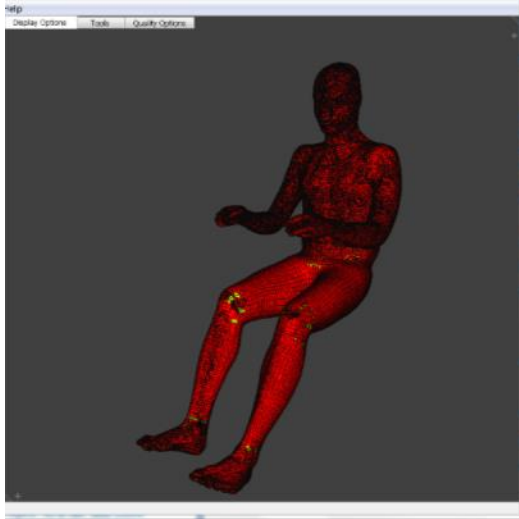
User describes functional constraints:

- Joints Kinematic between entities
- Contacts between entities

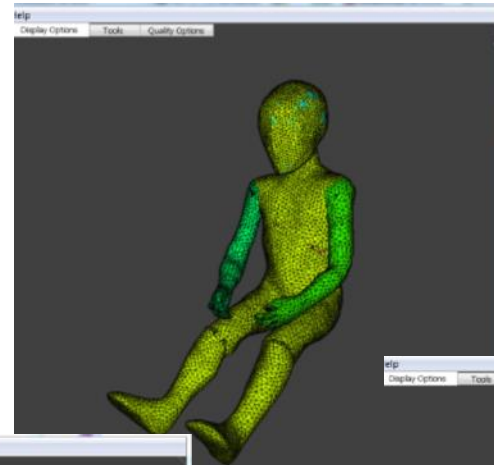
User defines model parameters affected by deformation

# PIPER: Framework

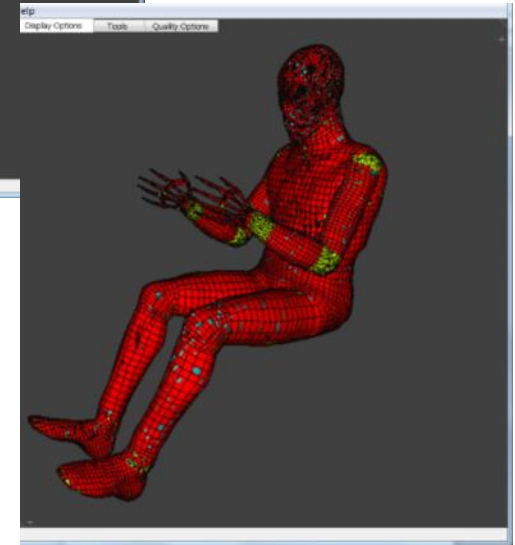
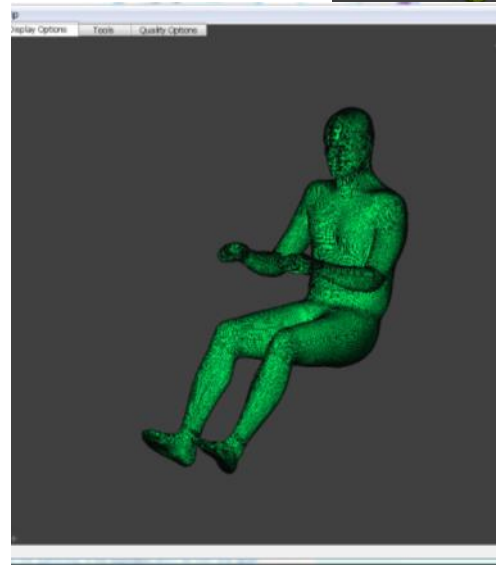
**GHBMC M50-O v001.19-2  
Pam-Crash (LAB)**



**Child model  
LS-Dyna**



**GHBMC M50-O\_v4-1-1  
LS-Dyna**



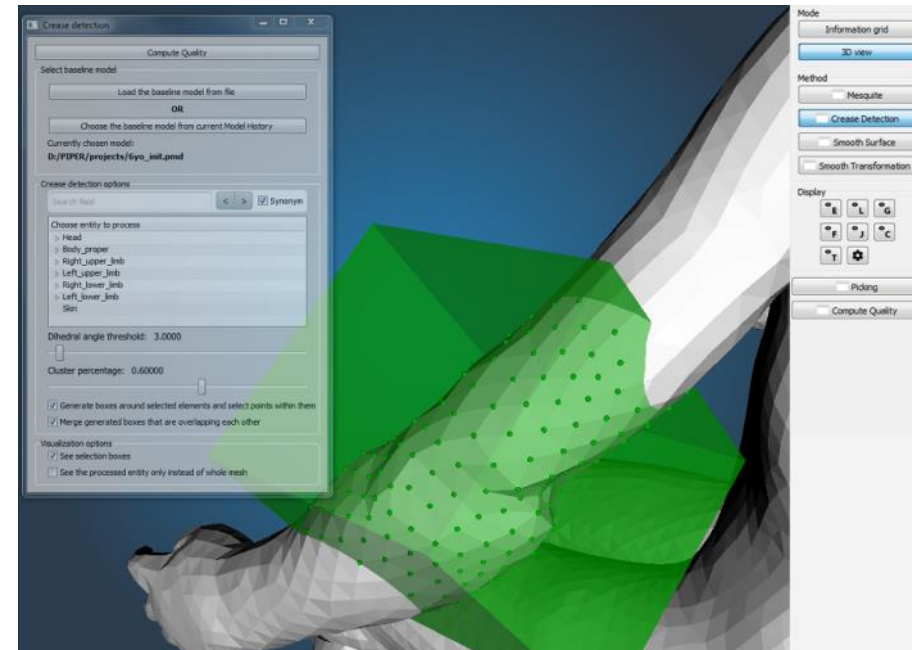
**Thums V3  
LS-Dyna (PDB)**

**FE code & HBM independency**

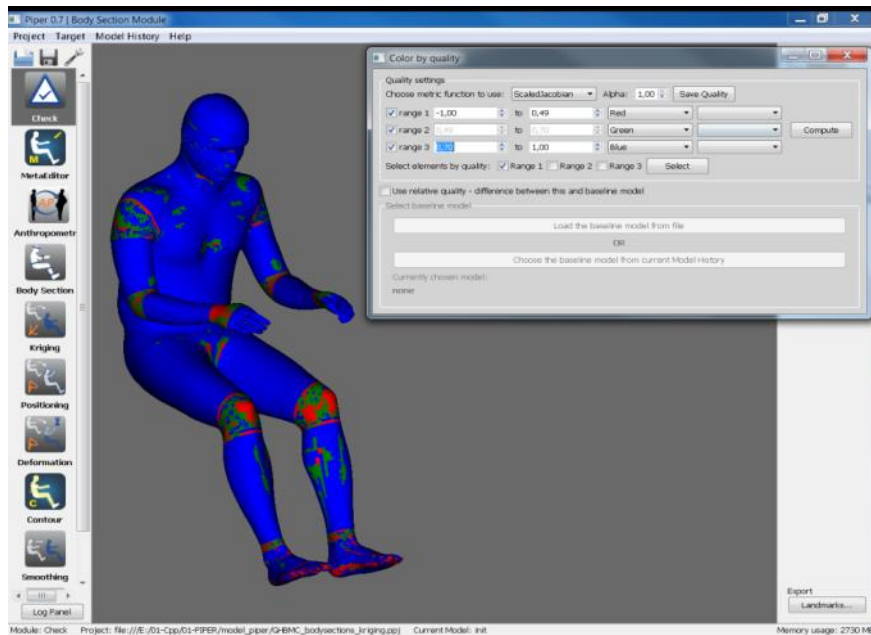
**ViVa**

# PIPER: Framework – Post processing tools

**Transformation smoother module:**  
Regional smoother to improve mesh quality after a model transformation



## Mesh Quality Tools



**Mesh Optimizer:**  
Optimize locally element quality  
(using MESQUITE Toolkit)



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# Anthropometric Personalization

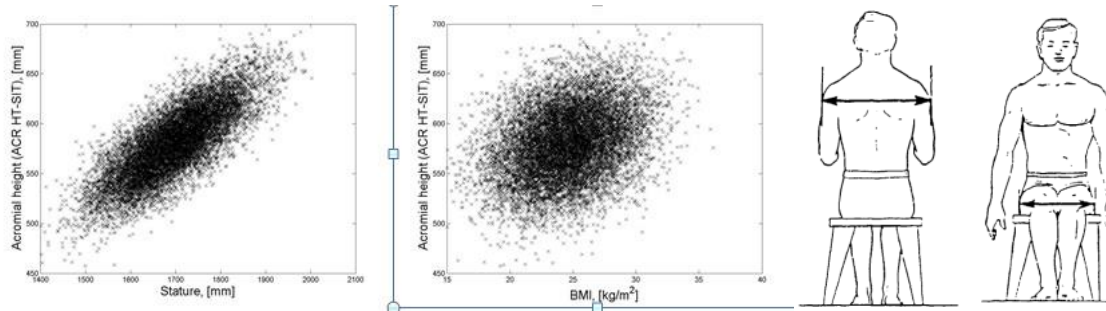
# Personalization: A priori knowledge & Targets

## 1 – Definition of target body dimensions: Anthropometric Module

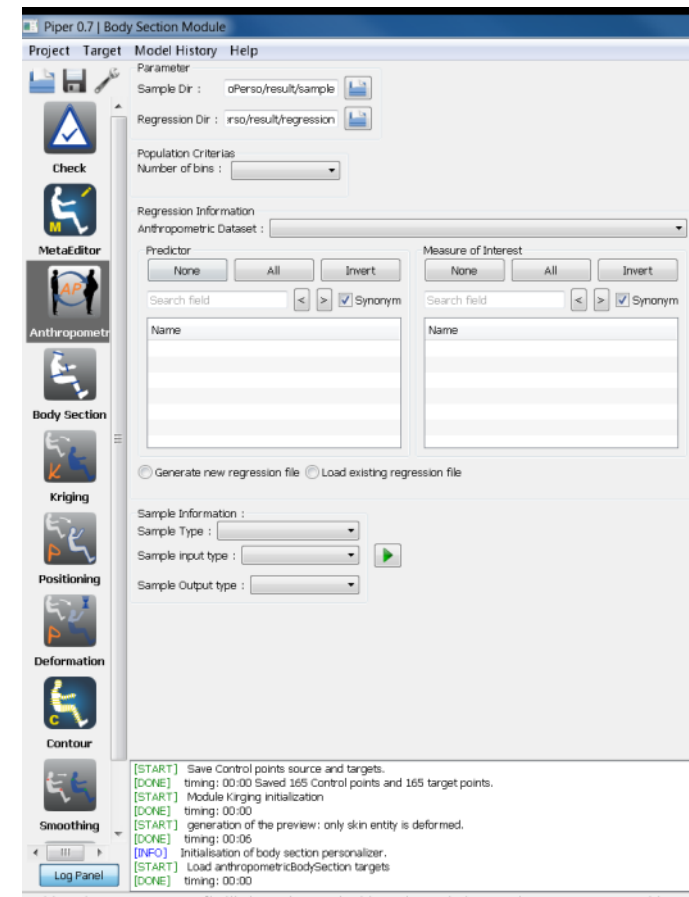
Use of existing database (ANSUR for adult, “Snyder” database for child anthropometry...) to predict body dimensions from user input

**Free choice  
of predictors (stature, gender, ...)**

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



**Provide full of set of anthropometric  
dimension targets**



Project Target Model History Help

Parameter

Sample Dir : oPerso/result/sample

Regression Dir : rrsso/result/regression

Population Criteria

Number of bins : [dropdown]

Regression Information

Anthropometric Dataset : [dropdown]

Predictor

[None] [All] [Invert]

Search field [dropdown] [Synonym] [checkbox checked]

Name [input field]

Measure of Interest

[None] [All] [Invert]

Search field [dropdown] [Synonym] [checkbox checked]

Name [input field]

Generate new regression file  Load existing regression file

Sample Information :

Sample Type : [dropdown]

Sample input type : [dropdown] [play button]

Sample Output type : [dropdown]

[START] Save Control points source and targets.

[DONE] timing: 00:00 Saved 165 Control points and 165 target points.

[START] Module Kriging initialization

[DONE] timing: 00:00

[START] generation of the preview: only skin entity is deformed.

[DONE] timing: 00:06

[INFO] Initialisation of body section personalizer.

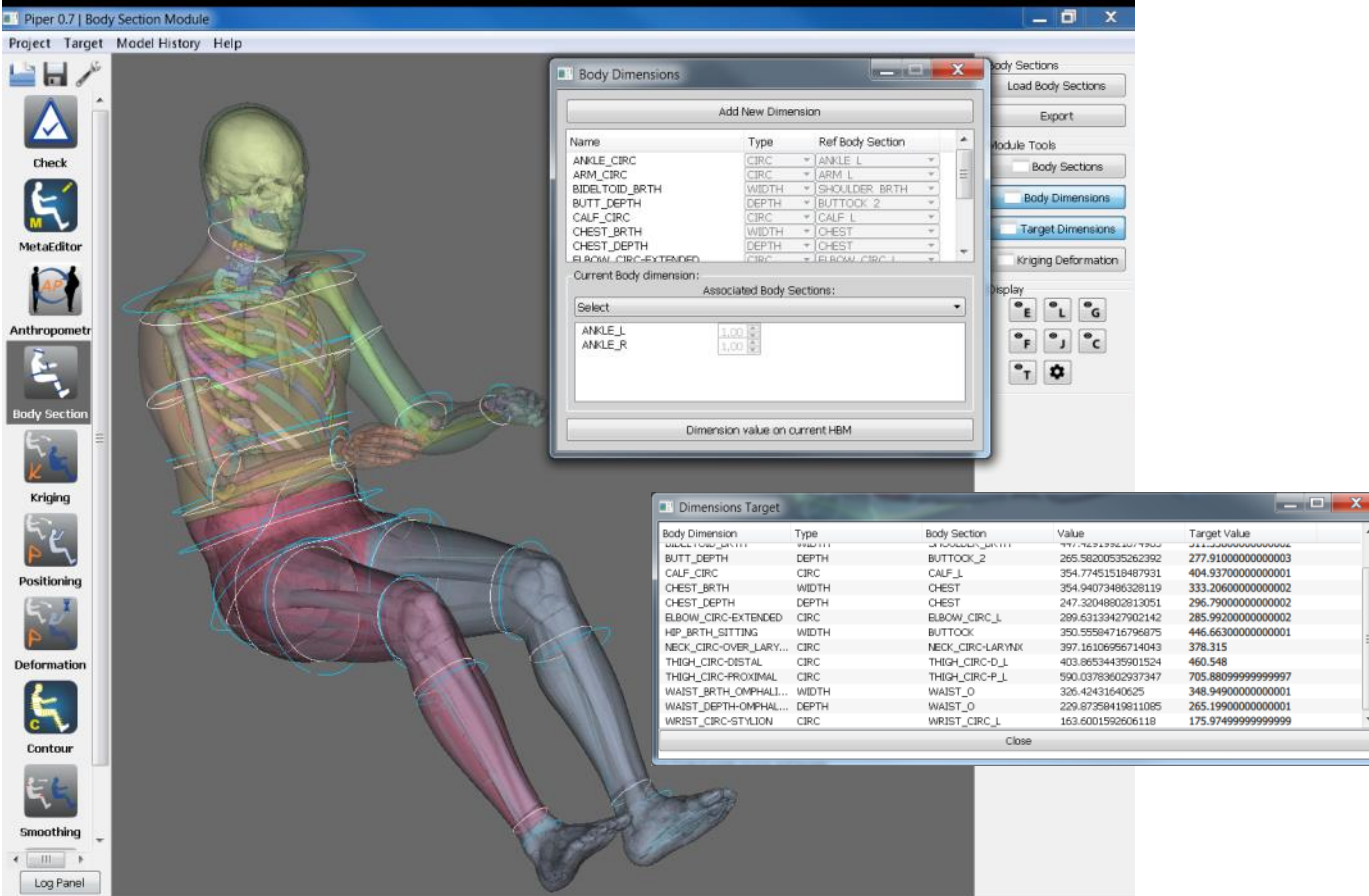
[START] Load anthropometricBodySection targets

[DONE] timing: 00:00

Module: Anthropometry Project: file:///E:/01-Cpp/01-PIPER/model\_piper/GHMC\_bodysections\_kriging.ppj Current Model: init

# Personalization: HBM Body dimensions

- 1 – Definition of target body dimensions: Anthropometric Module
  - 2 – Describe body dimensions on the HBM: Body Section Module
- Define on HBM body dimensions => link with anthropometric targets

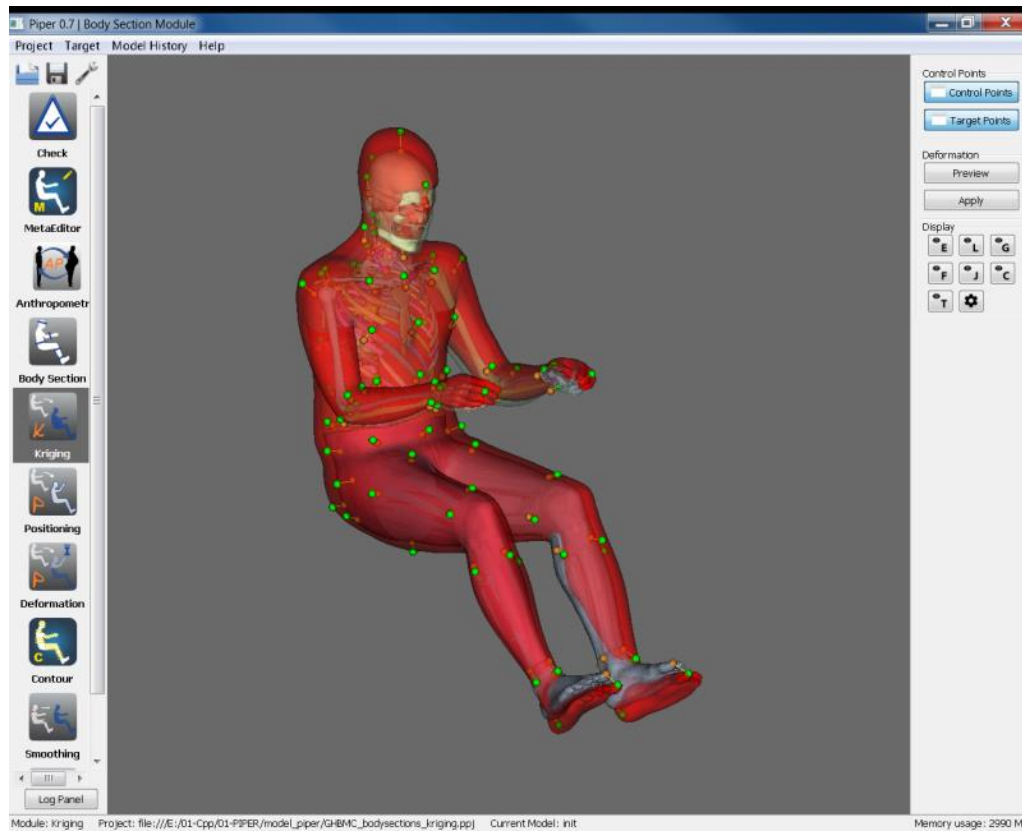


The screenshot displays the Piper 0.7 Body Section Module interface. The main window shows a 3D human model with various body dimensions highlighted in different colors. A 'Body Dimensions' dialog box is open, showing a list of dimensions and their associated body sections. A 'Dimensions Target' dialog box is also open, displaying a table of target dimensions and their values.

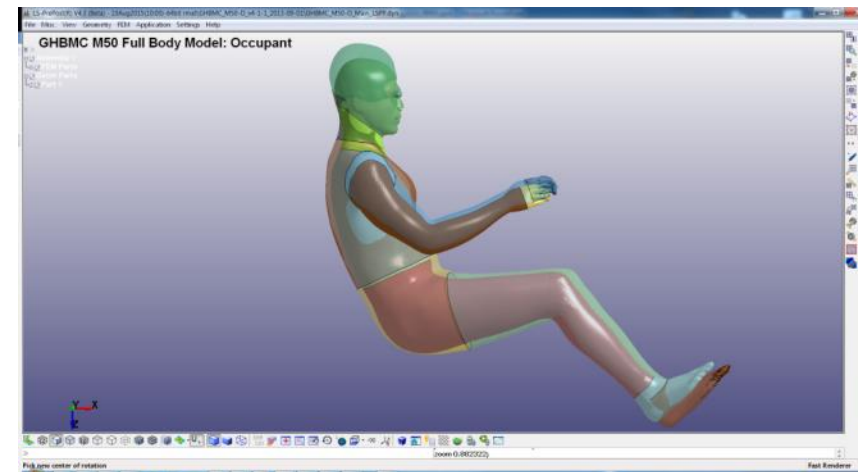
Body Dimension	Type	Body Section	Value	Target Value
ANKLE_CIRC	CIRC	ANKLE_L	177.76249962079502	211.22600000000000
ARM_CIRC	CIRC	ARM_L	265.58200525282392	277.91000000000000
BIDELTOID_BRTH	WIDTH	SHOULDER_BRTH	354.77451518487931	404.93700000000000
BUTT_DEPTH	DEPTH	BUTTOCK_2	354.94073486328119	333.20600000000000
CALF_CIRC	CIRC	CALF_L	247.32048802813051	296.79000000000000
CHEST_BRTH	WIDTH	CHEST	289.53123427902142	285.99200000000000
CHEST_DEPTH	DEPTH	CHEST	350.55584716795675	446.66300000000000
CHEST_DEPTH	DEPTH	CHEST	397.16106956714043	378.315
ELBOW_CIRC-EXTENDED	CIRC	ELBOW_CIRC_L	403.86534435901524	460.548
HIP_BRTH_SITTING	WIDTH	BUTTOCK	590.03783602937347	705.88099999999997
NECK_CIRC-OVER_LARYNX	CIRC	NECK_CIRC-LARYNX	326.42431640625	348.94900000000000
THIGH_CIRC-DISTAL	CIRC	THIGH_CIRC-D_L	229.87358419811085	265.19900000000000
THIGH_CIRC-PROXIMAL	CIRC	THIGH_CIRC-P_L	163.6001592606118	175.97499999999999
WAIST_BRTH-OMPHALOM	WIDTH	WAIST_O		
WAIST_DEPTH-OMPHALOM	DEPTH	WAIST_O		
WRIST_CIRC-STYLION	CIRC	WRIST_CIRC_L		

# Personalization: Deformation

- 1 – Definition of target body dimensions
- 2 – Describe body dimensions on the HBM: Body Section Module
- 3 – **Apply deformation:**  
Dual Kriging interpolation method is used to deform the model



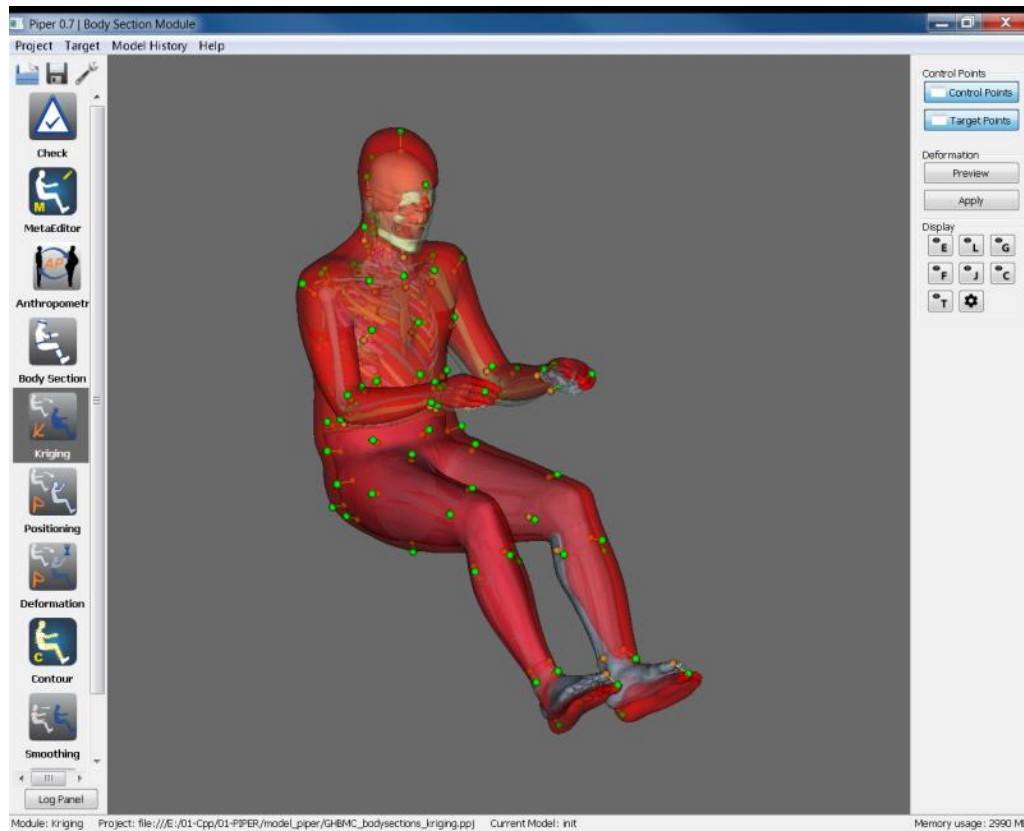
## Updated and Baseline FE models



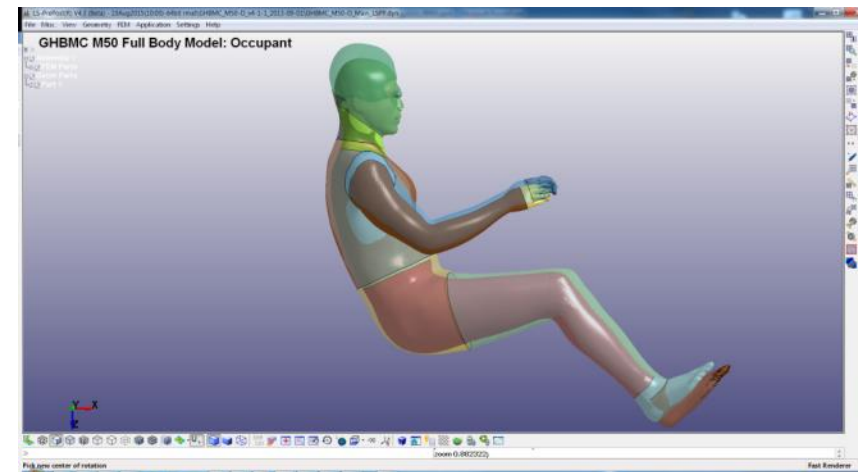


# Personalization: Deformation

- 1 – Definition of target body dimensions
- 2 – Describe body dimensions on the HBM
- 3 – Apply deformation
- 4 – If needed, material properties and shell thickness or other FE model parameter defined in model metadata can be modified using dedicated PIPER module**



## Updated and Baseline FE models



# Personalization

## Limitations on Child scaling:

- extend scaling module to consider individual body segment length scaling
- Methodology has been already defined and tested
- Still to complete the integration

## Personalization using Statistical Shape Models of full skeleton:

- Provide average representative shapes for a population
- Challenge: Ensure the ability of the deformed model to be used in a crash simulation



## Improvement of Personalization workflow:

=> Smooth the workflow from user point of view



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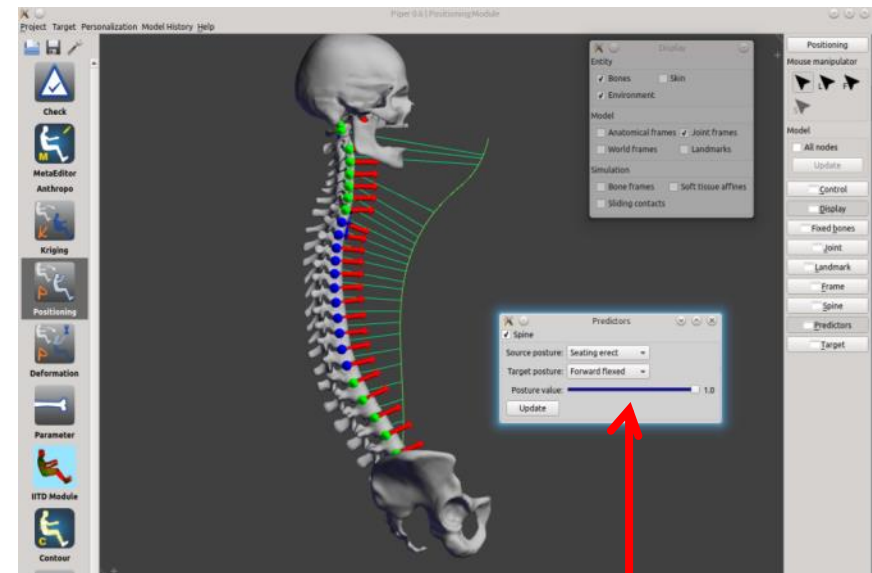
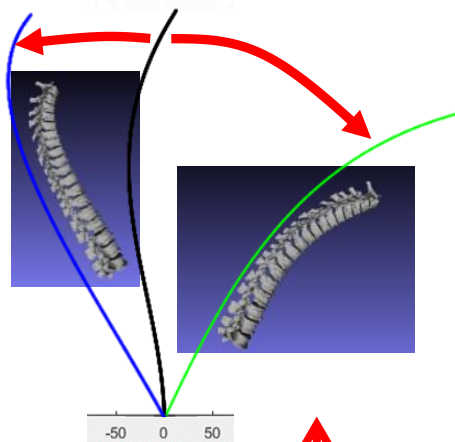
### Positioning

# PIPER: Positioning Workflow

## 1 – Definition of target position: Interactive Positioning Module

- Interactive positioning using a lightweight physics model generated from imported HBM
- Functional constraints: bone collision, sliding contacts, kinematic joints...
- User constraints:
  - Fixed bones, Joint angles for kinematics joints, relative position/orientation of bones, Target positions of landmarks,
- Biomechanical a priori knowledge on posture to produce more realistic/physiological target posture

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



# PIPER: Positioning Workflow

Example of positioning with interactive model:



# PIPER: Positioning Workflow

1 – Definition of target position: Interactive Positioning Module

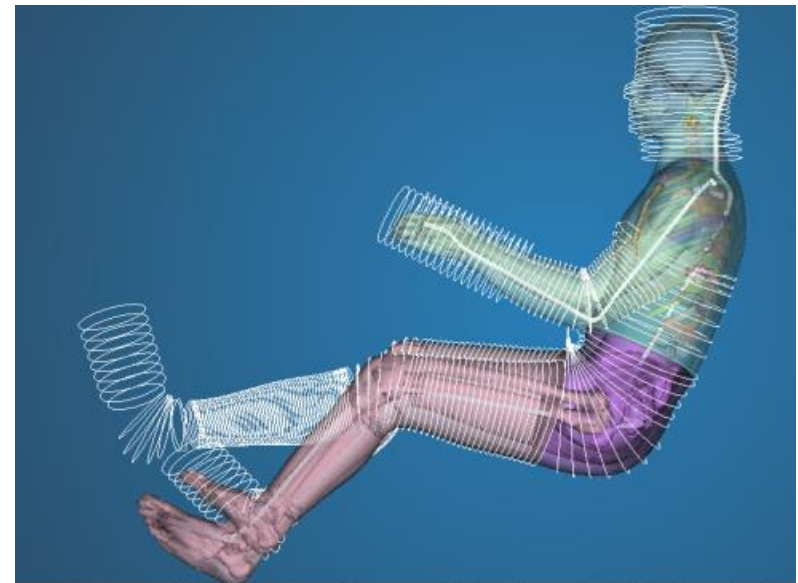
**2 – Apply deformation to HBM:**

- two approaches available

**Physics-based Transformation<sup>1</sup>:**



**Contours-based Transformation<sup>2</sup>:**



[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.

## PIPER: Positioning Workflow

- 1 – Definition of target position:
- 2 – Apply deformation to HBM
- 3 – Improve mesh quality on region with mesh distortion: Transformation smoother module**
- 4 – Update FE model**



**Before Positioning**



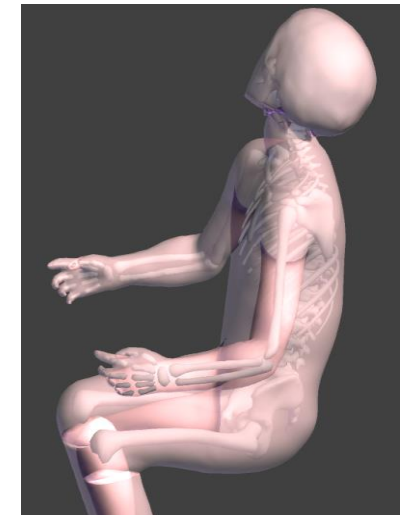
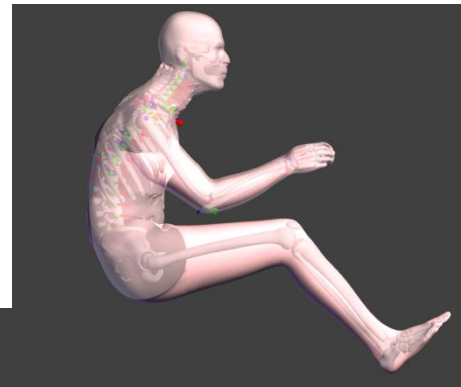
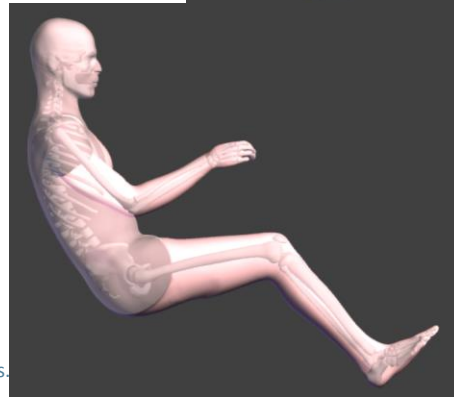
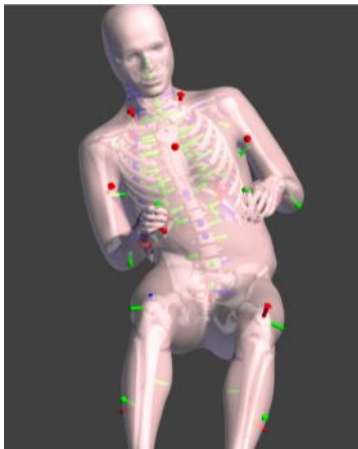
**After Positioning**

## PIPER: Positioning Workflow

Mainly tested with success (runable output model) on sagittal movement

### Limitations:

- Mesh quality can be strongly affected by deformation for large range of motion, independently of the deformation method used.
- => Finite Element HBM design can limit their usability in PIPER tools (continuous mesh, lack of sliding component bones/soft tissues...) *Jolivet et al. STAPP 2015*
- No interaction between HBM and environment.





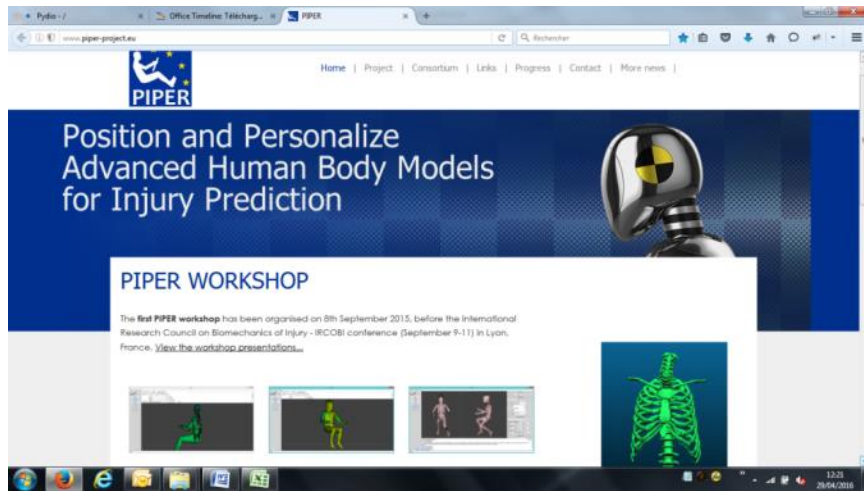
## Next Step

- External beta testing of PIPER software:
  - Identify gap between expectations of users and functionalities implemented in PIPER software to define priorities for the version released at then end.
    - Aggressive timeline
    - NDA
- Open Source management structures: maintenance, support....

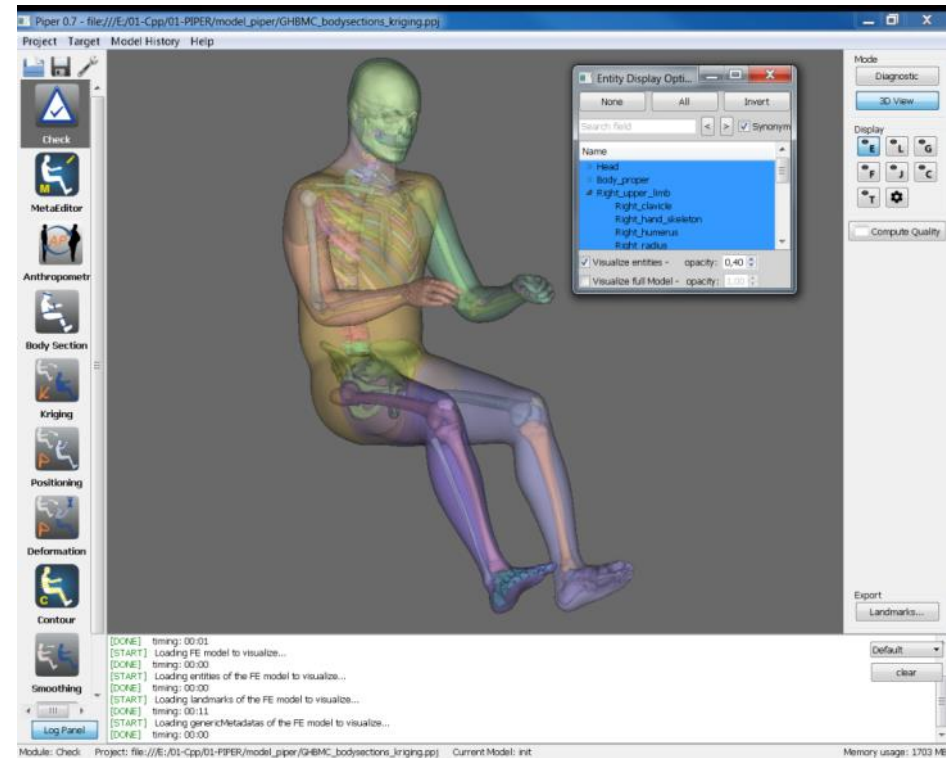
## Expected Outcomes & Perspectives

### **At the end of the project, PIPER software:**

- Unique, State of the art on methodologies from different fields
- Take into account actual workflow from industries & academic users
- FE code & model independent
- Provide solution(s) for positioning & personalizing human body model in a unified framework
- Modular architecture allowing integration of other efforts
- Preliminary guidelines



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



The research leading to these results has received funding from the European Seventh Framework Programme (FP7/2007-2013) under grant agreement n°605544