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

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6th 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 ≠ population variability

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

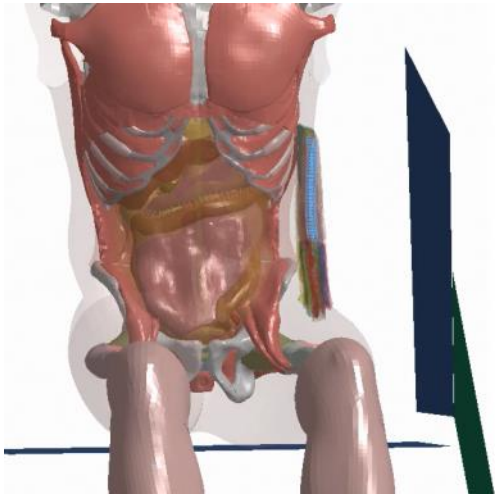
-- Increasingly complex to develop (expertise, funding, academic & business models?)

-- 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)

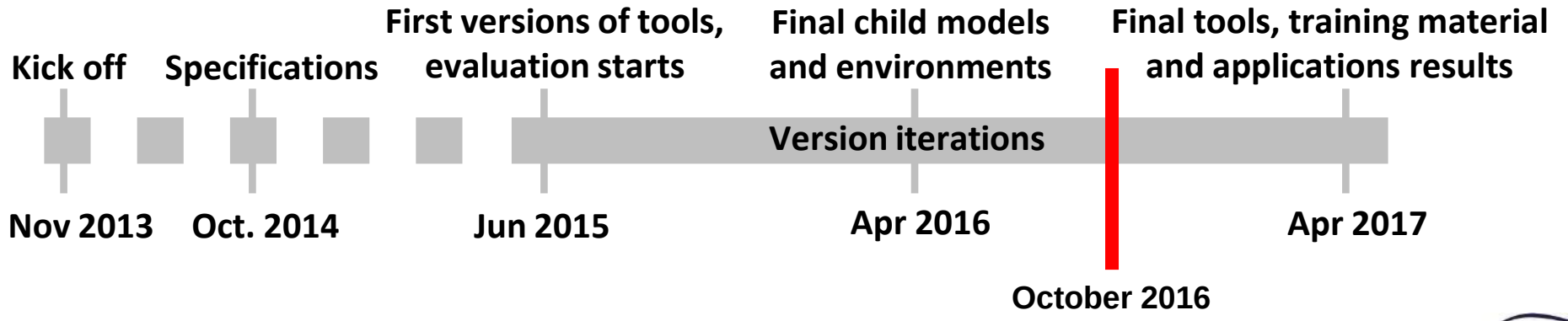


GHBMC (source: LBMC)

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)

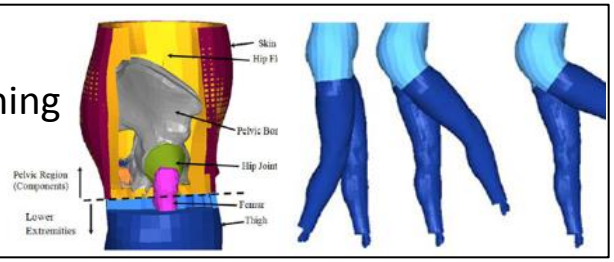


PIPER: Partners

FE modeling for impact

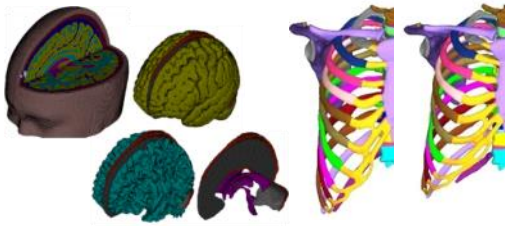
Academics

Hip positioning



FITT

Subject & population specific modeling



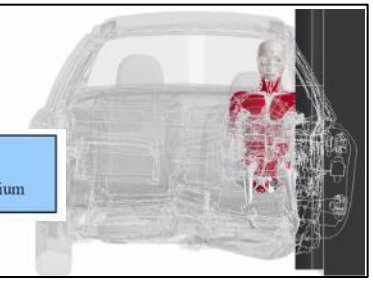
KTH *CEESAR*

UCBL

TUB

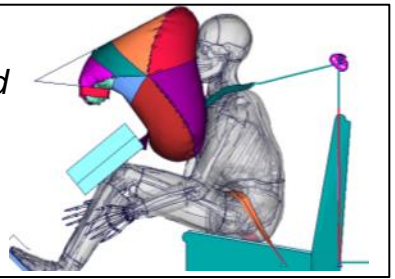
Industry

LAB Peugeot Renault



GHBMC
Global Human Body Models Consortium

PDB Partnership for Dummy Technology and Biomechanics (PDB)



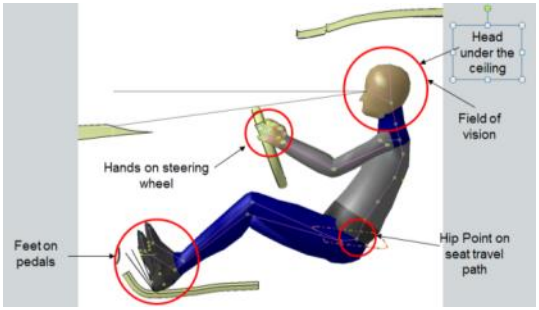
Other fields

Academics

Femur statistical modeling

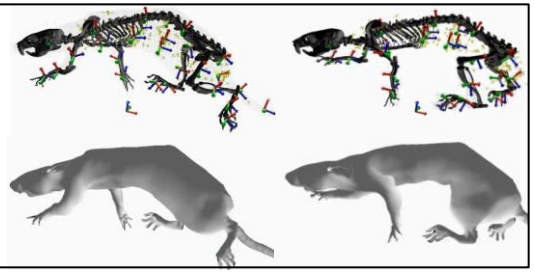
SOTON

Postural prediction



UCBL

Realtime Postural change

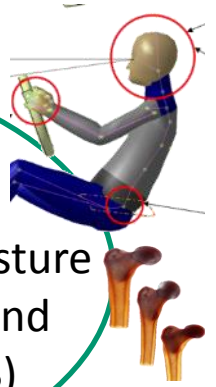


INRIA

PIPER: Overall approach and project structure

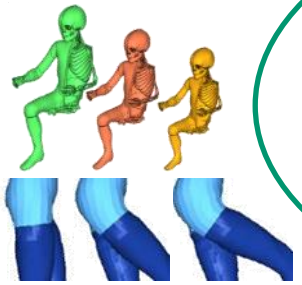
WP1: Specs & apps

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

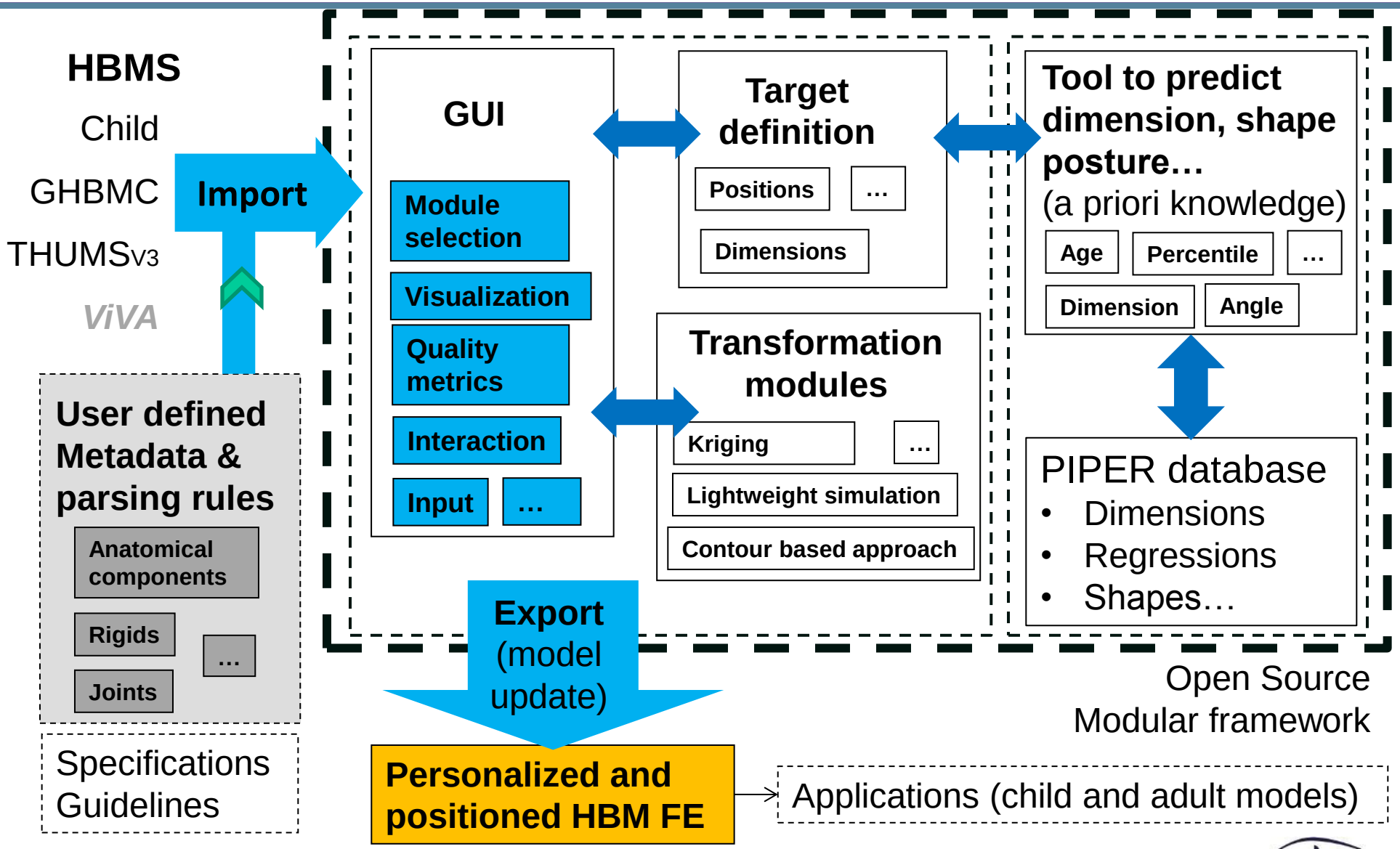
Aim: transform full FE models to describe other postures and populations (tools)

WP4: Dissemination

Wide distribution, Open Source tools

WP5: Management

PIPER: Overall approach and project structure



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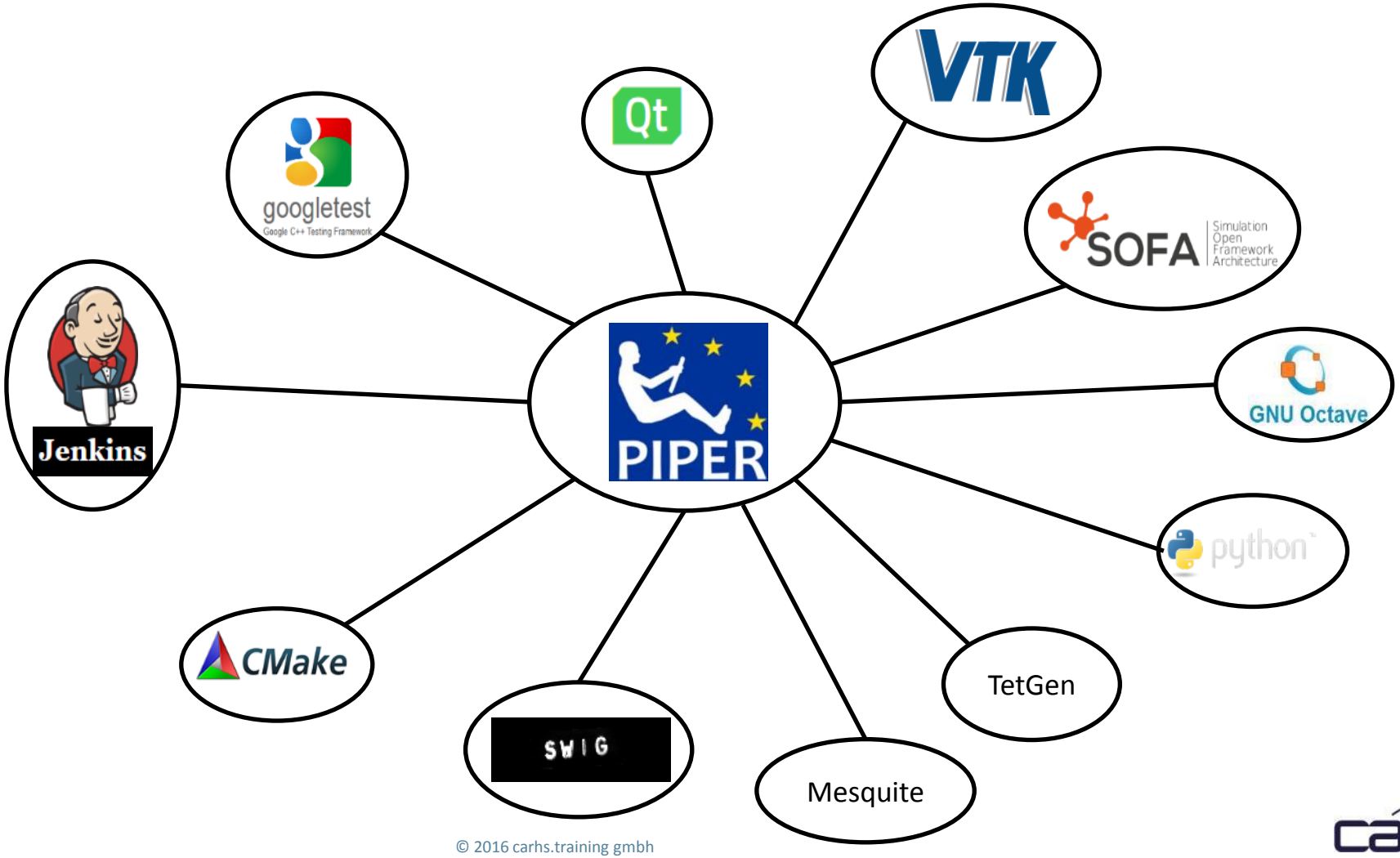
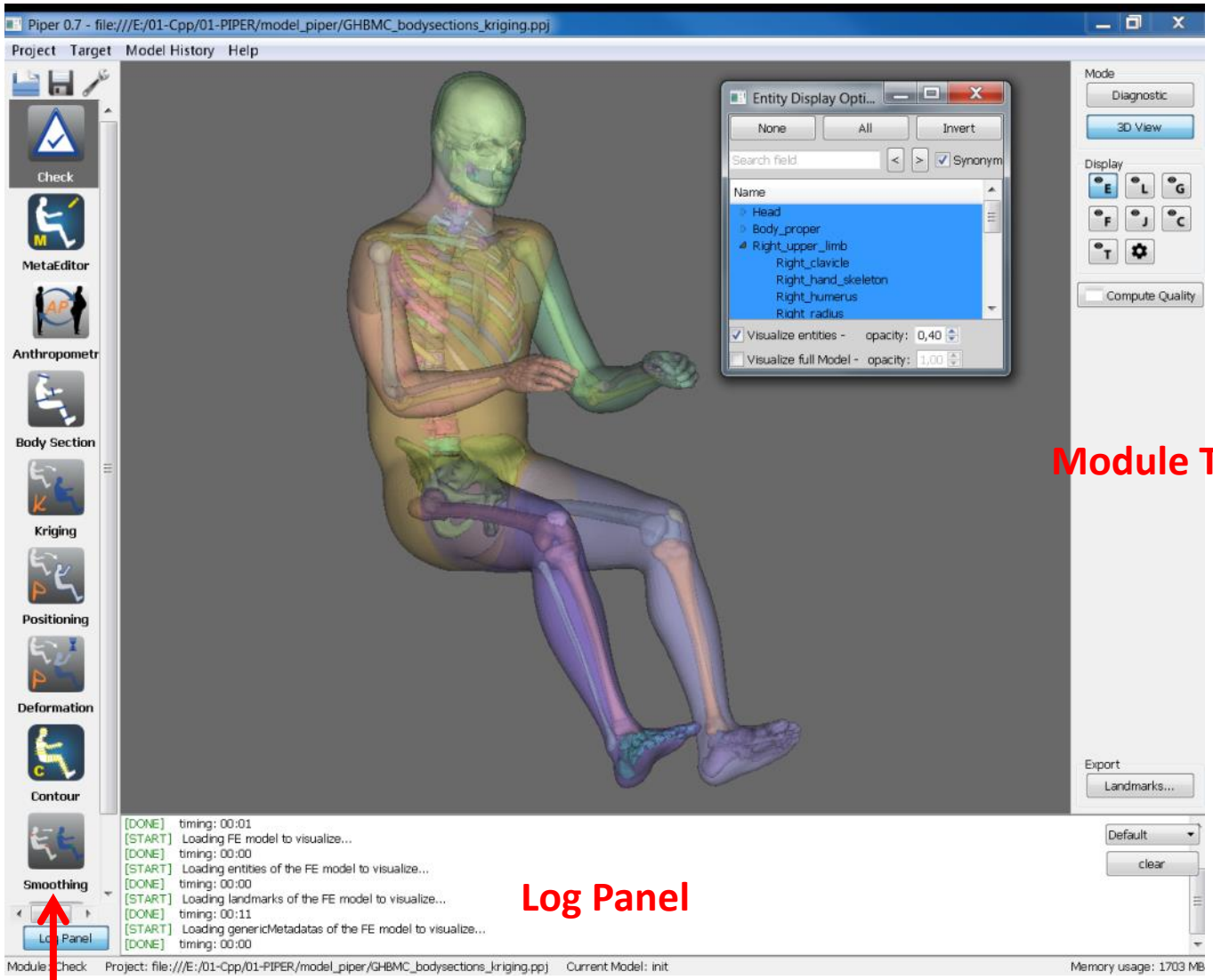
Framework

PIPER:

PIPER tools license: GPL v2 or Later



PIPER: Framework



Module Tools

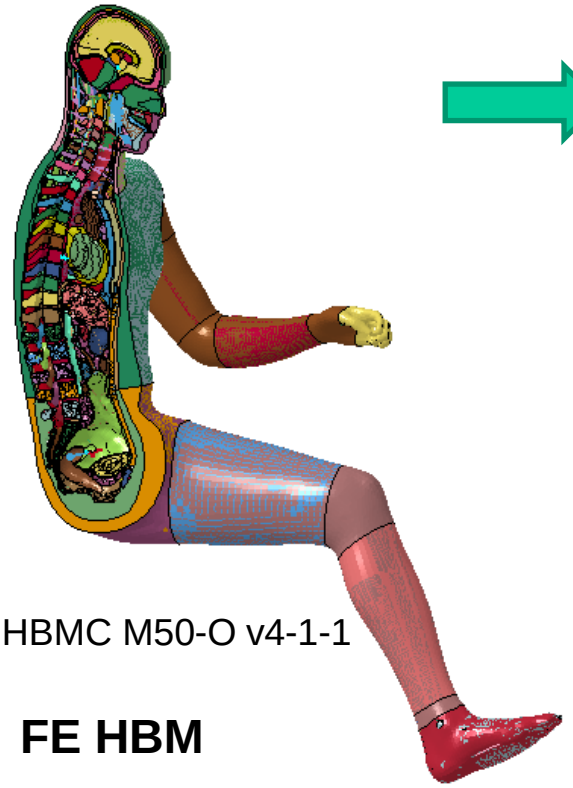
Log Panel

Module Selection

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

PIPER: Framework

Import FE HBM



GHBMC M50-O v4-1-1

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

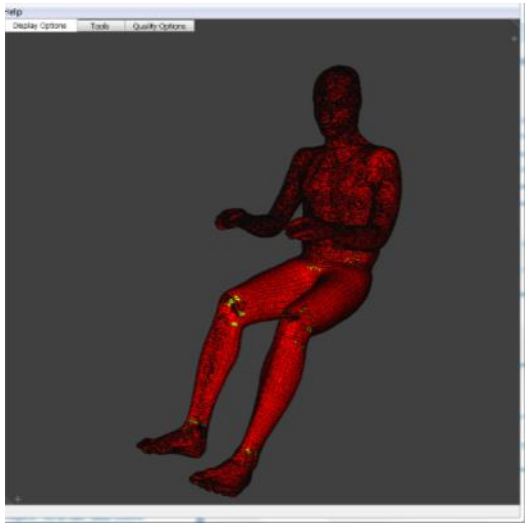
User defines association between:
Group of elements ⇔ Anat. Entities
Group of nodes ⇔ Landmarks

User describes functional constraints:
- Joints Kinematic between entities
- Contacts between entities

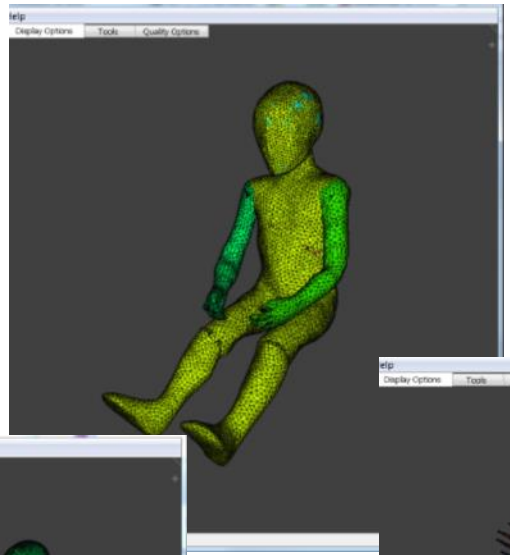
User defines model parameters affected by deformation

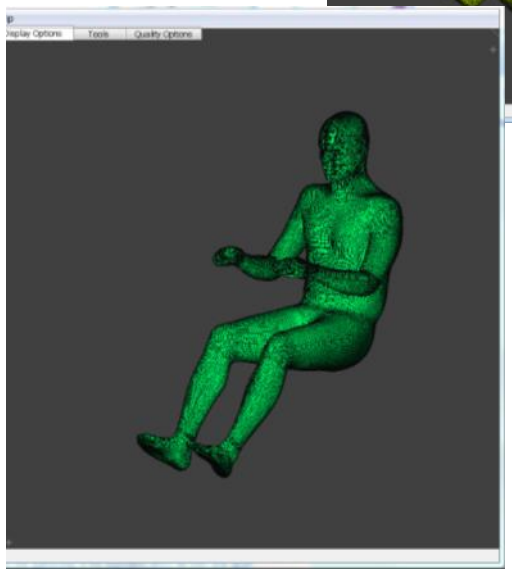
PIPER: Framework

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

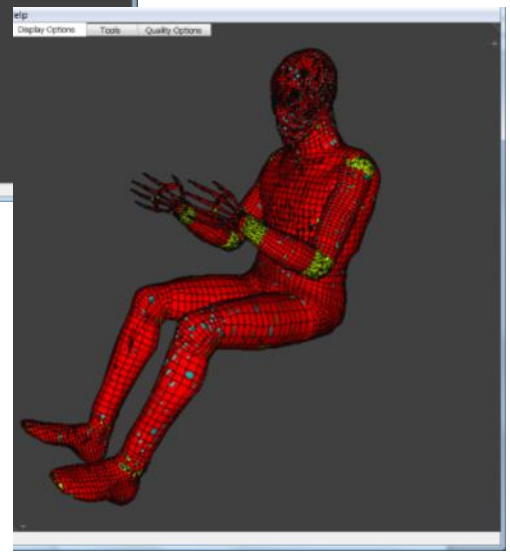


Child model
LS-Dyna





GHBMC M50-O_v4-1-1
LS-Dyna



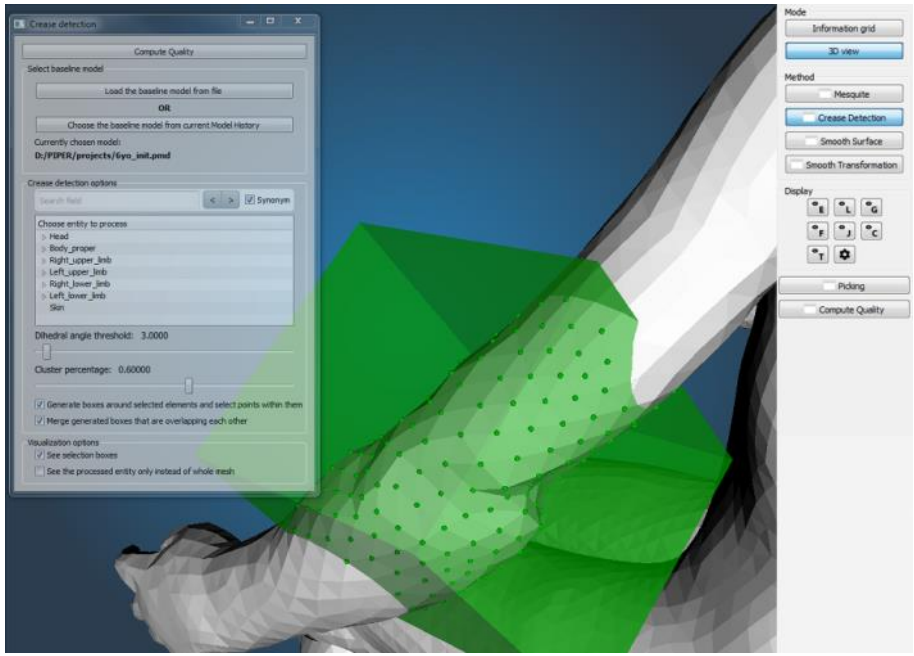
Thums V3
LS-Dyna (PDB)

FE code & HBM independency

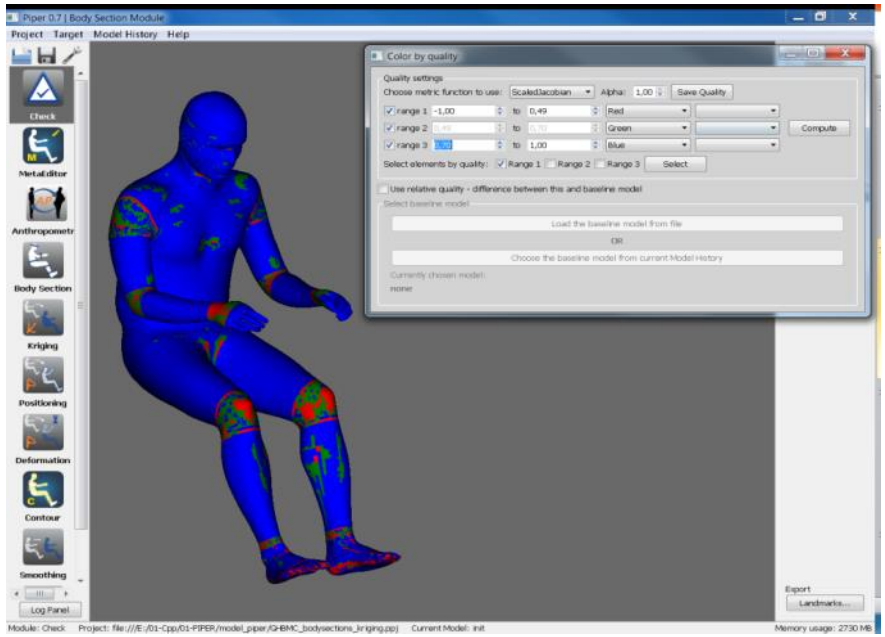
ViVa

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

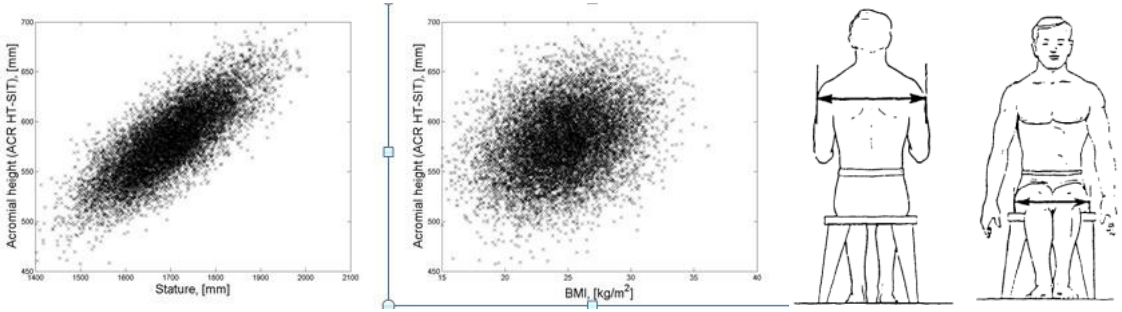
Personalization: A priori knowledge & Targets

1 – Definition of target body dimensions: Anthropometric Module

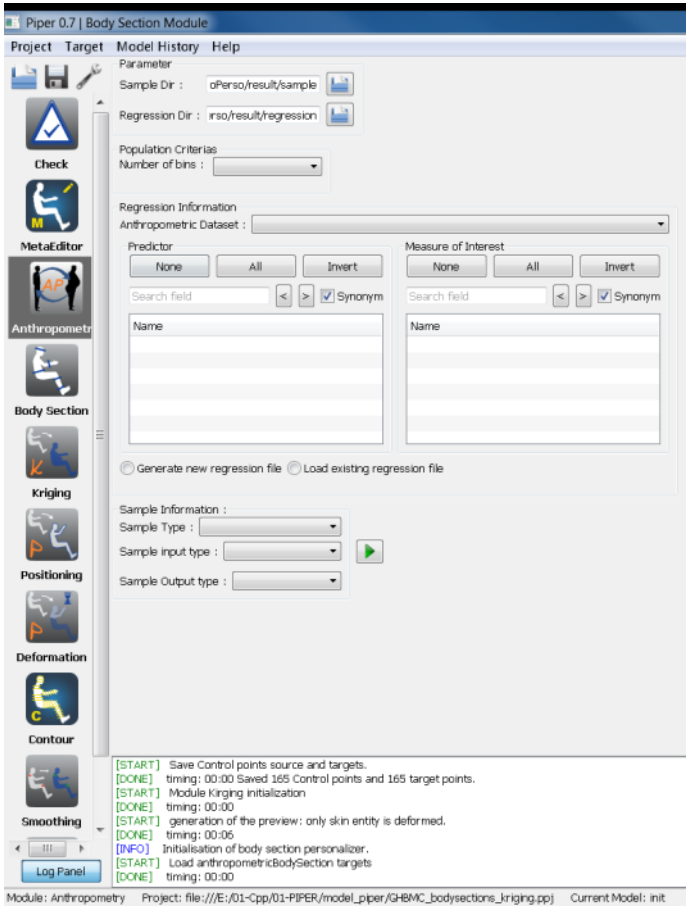
Use of existing database (ANSUR for adult, “Snyder” database for child anthropometry…) to predict body dimensions from user input

Free choice
of predictors (stature, gender, …)

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



Provide full of set of anthropometric dimension targets

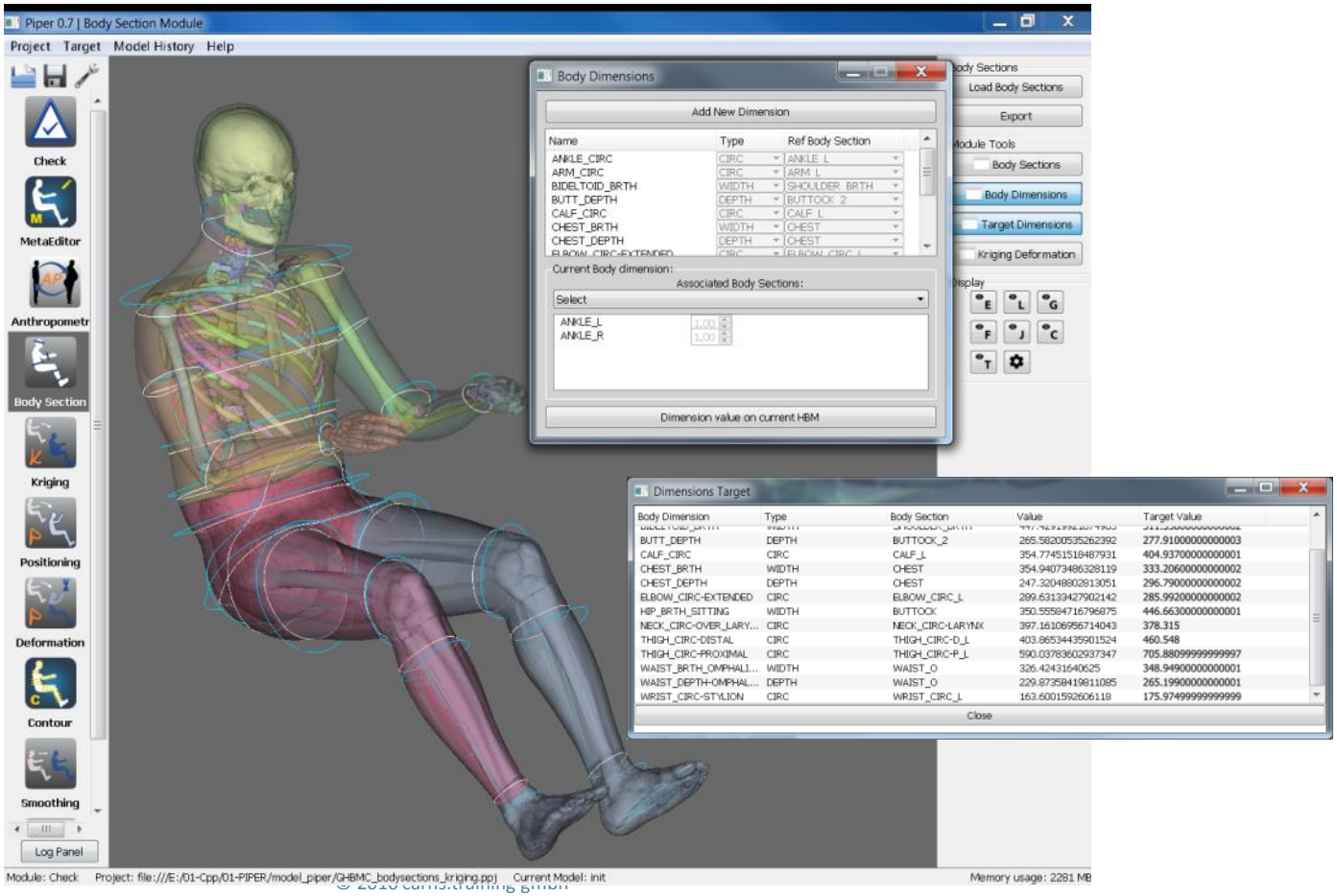


Personalization: HBM Body dimensions

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



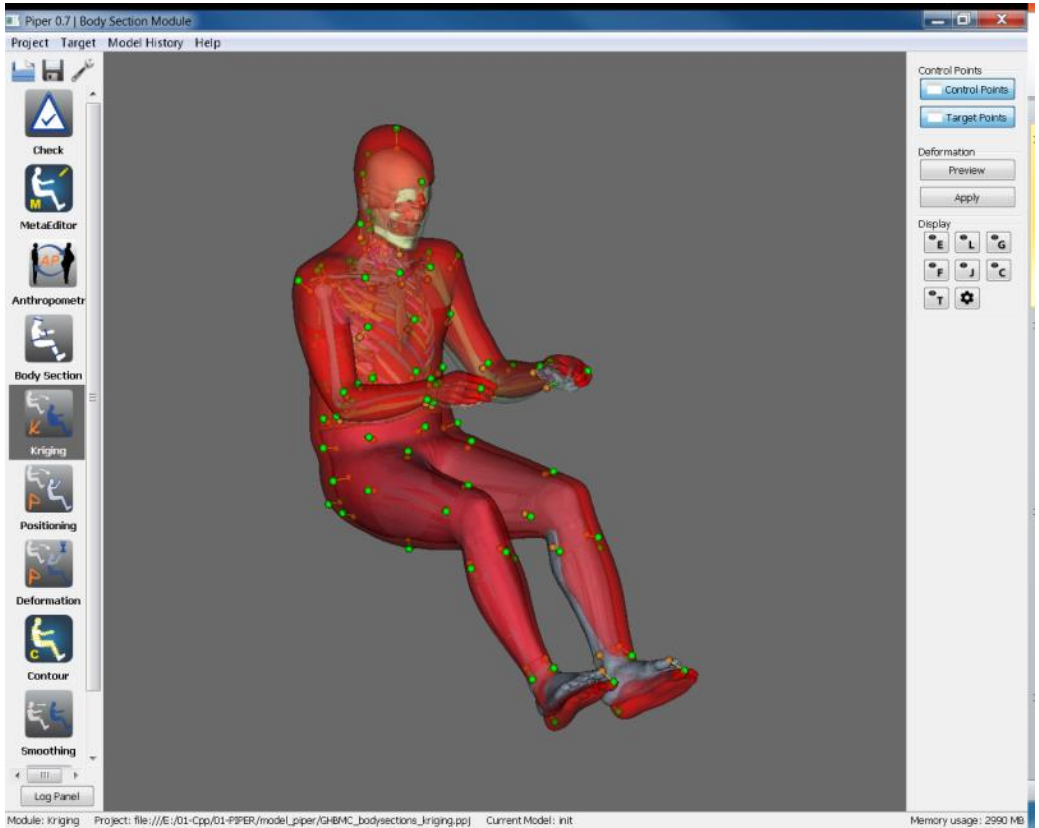
Personalization: Deformation

1 – Definition of target body dimensions

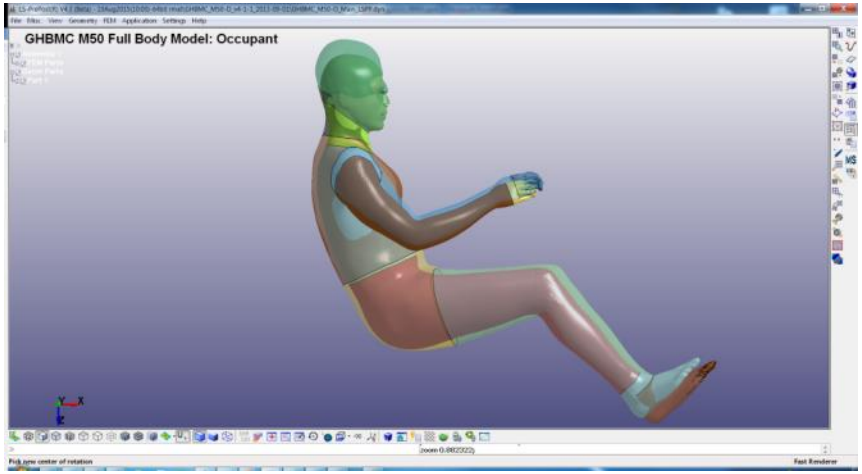
2 – Describe body dimensions on the HBM: Body Section Module

3 – Apply deformation:

Dual Kriging interpolation method is used to deform the model

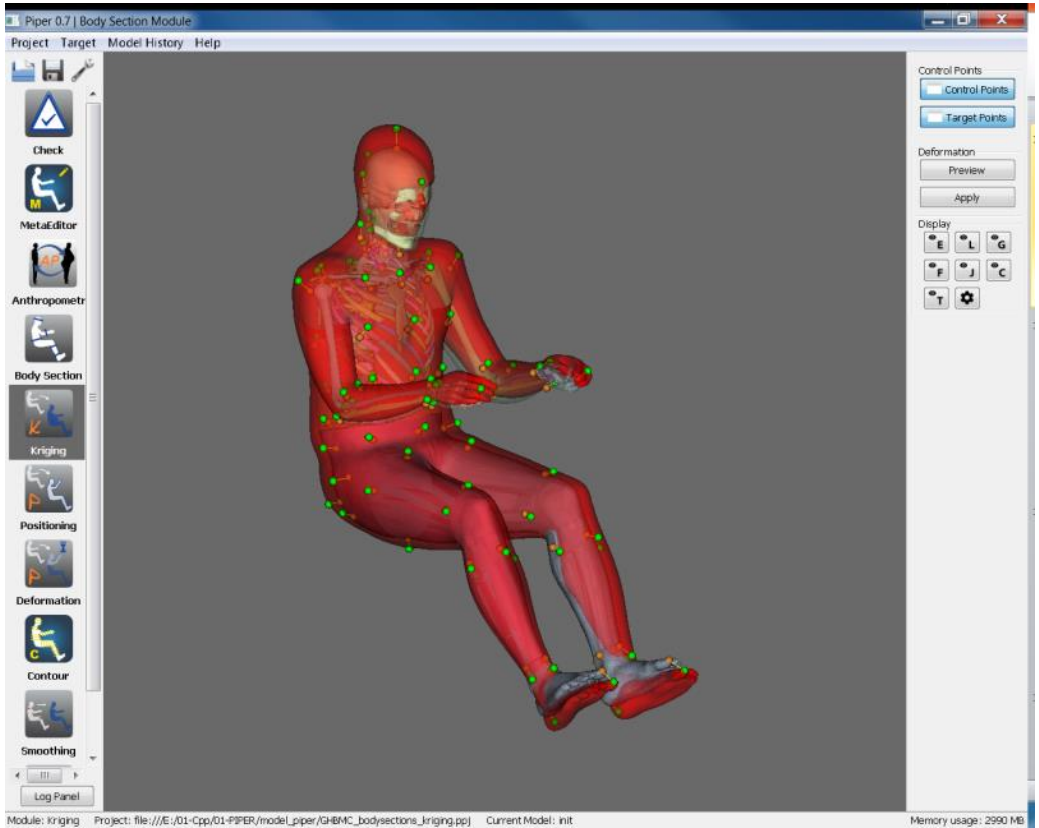


Updated and Baseline FE models

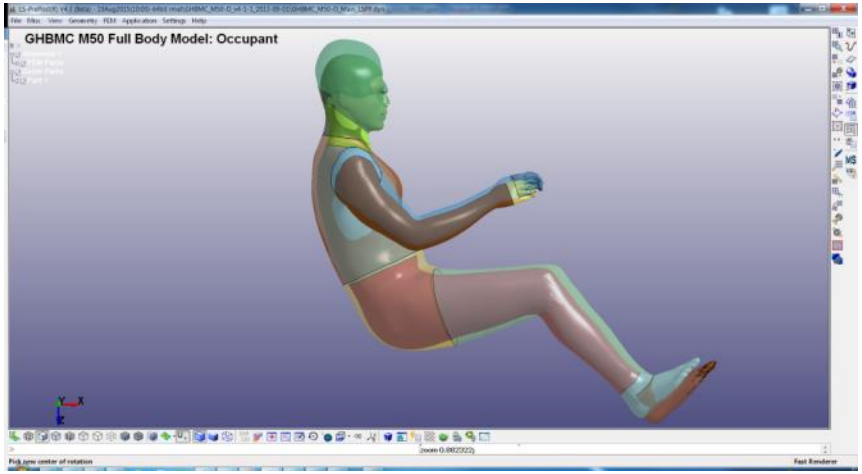


Personalization: Deformation

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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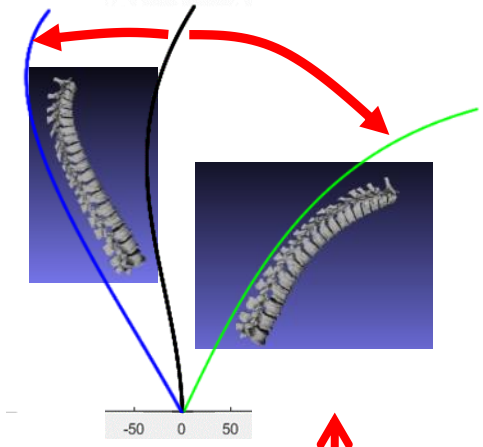
Positioning

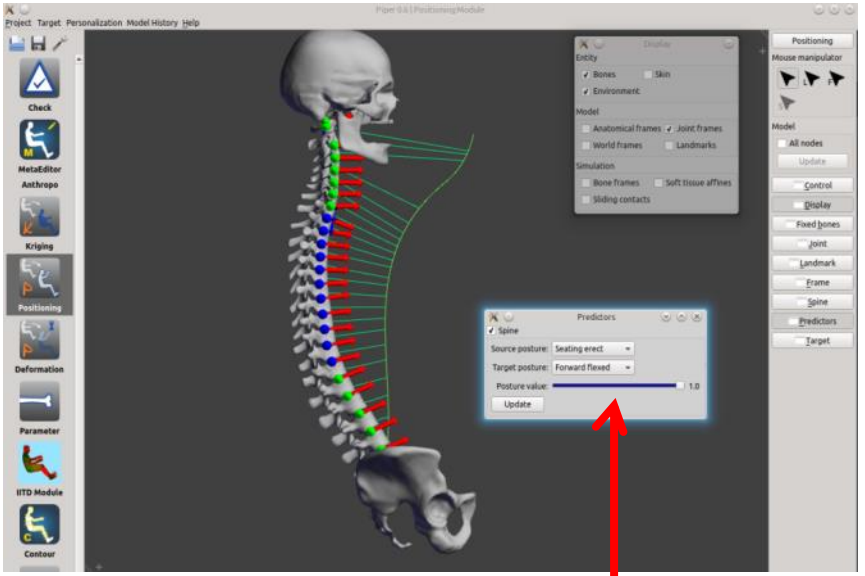
PIPER: Positioning Workflow

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

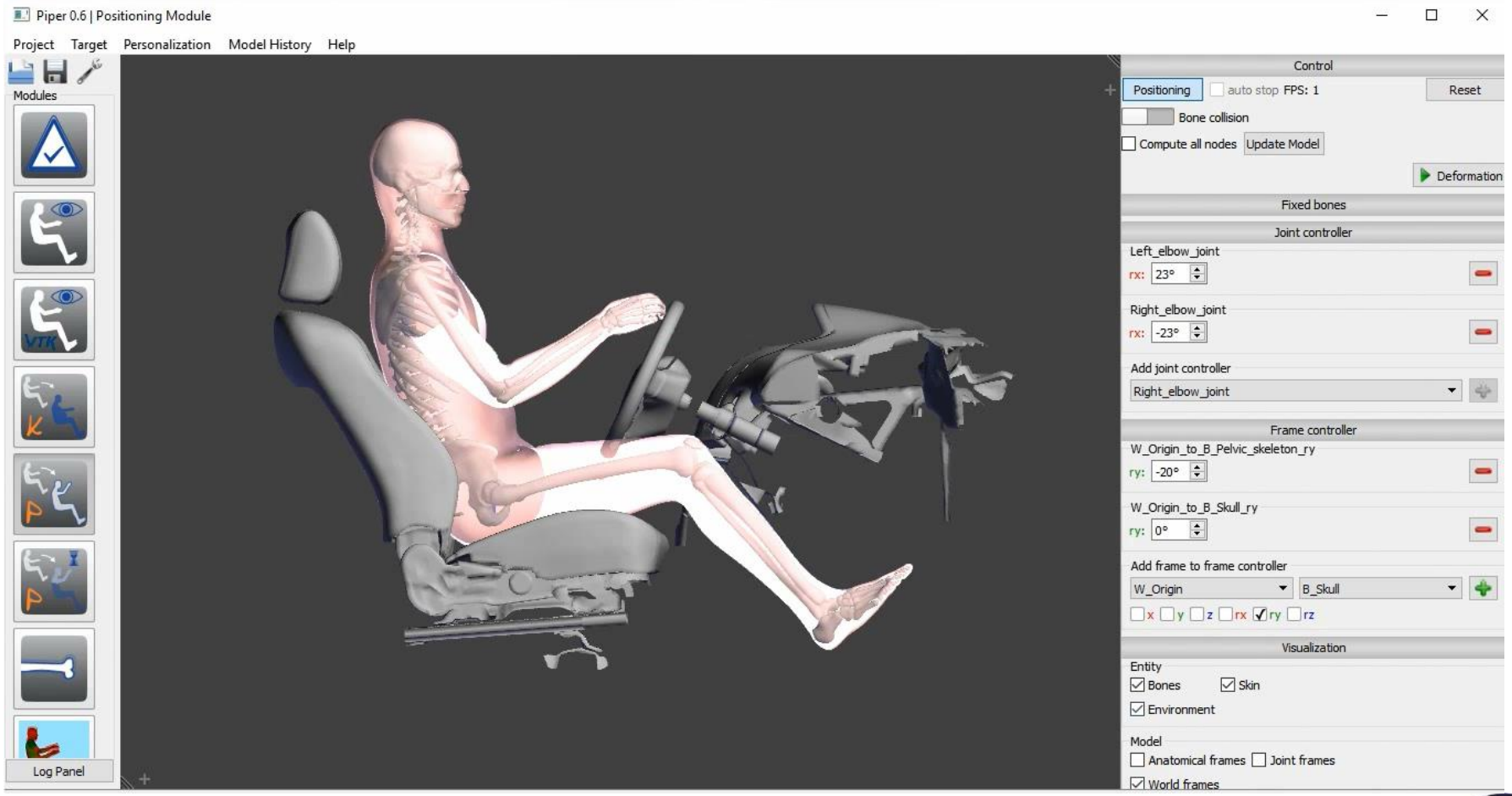
Physiological prediction of spine posture, based on known postures, and user targets





PIPER: Positioning Workflow

Example of positioning with interactive model:



PIPER: Positioning Workflow

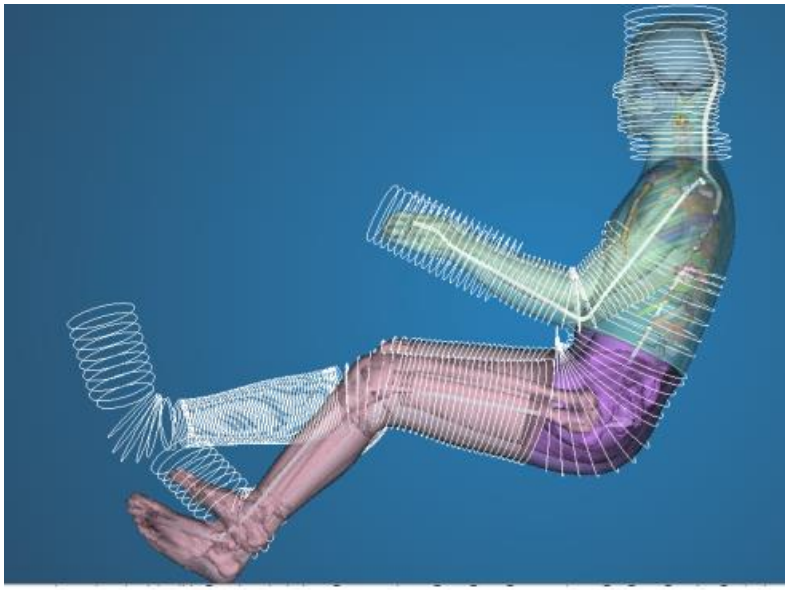
1 – Definition of target position: Interactive Positioning Module

2 – Apply deformation to HBM:

- two approaches available

Physics-based Transformation[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.

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

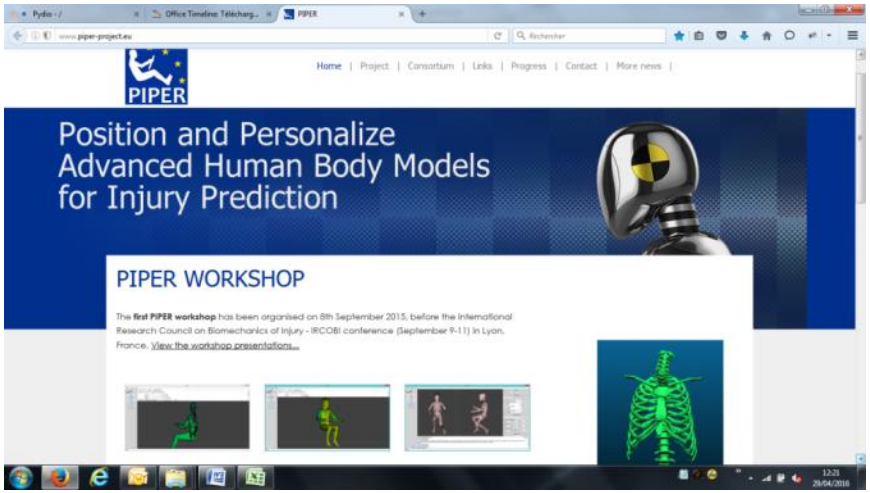
- External beta testing of PIPER software:
  - Identify gap between expectations of users and functionalities implemented in PIPER software to define priorities for the version released at then end.
    - Aggressive timeline
    - NDA

- Open Source management structures: maintenance, support….

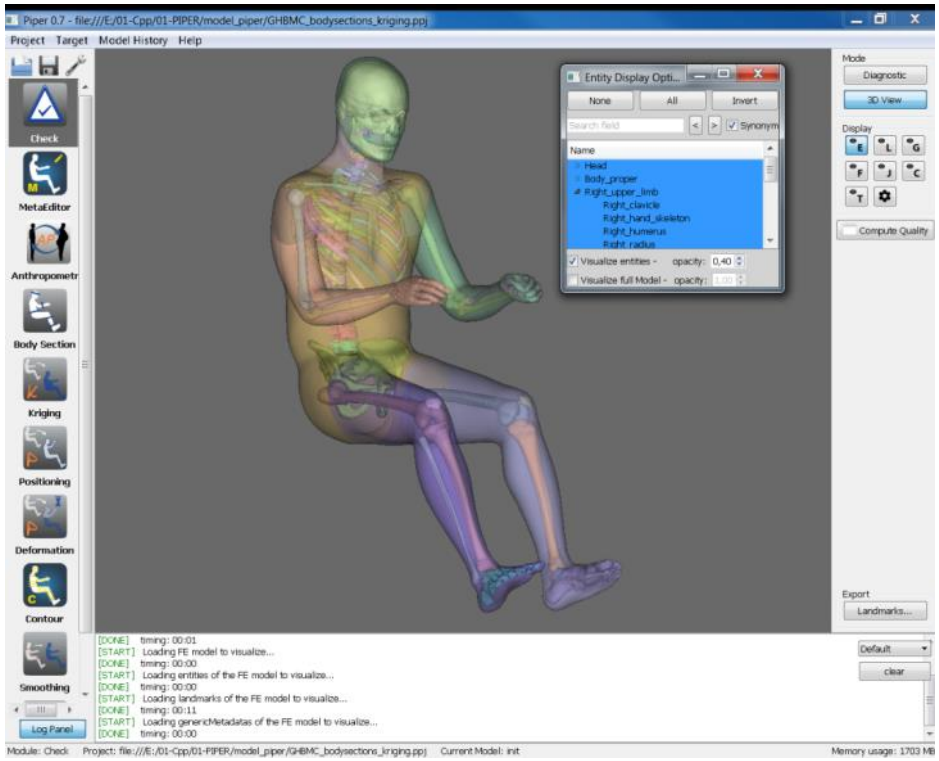
Expected Outcomes & Perspectives

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