

Towards a More Standardized Application of Human Body Models

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HUMAN MODELING
AND SIMULATION
IN AUTOMOTIVE ENGINEERING

Agenda



1. The THUMS User Community
2. TUC Validation Repository
3. Reference Points to standardise pre- and post-processing procedures





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Associated Partners



bast



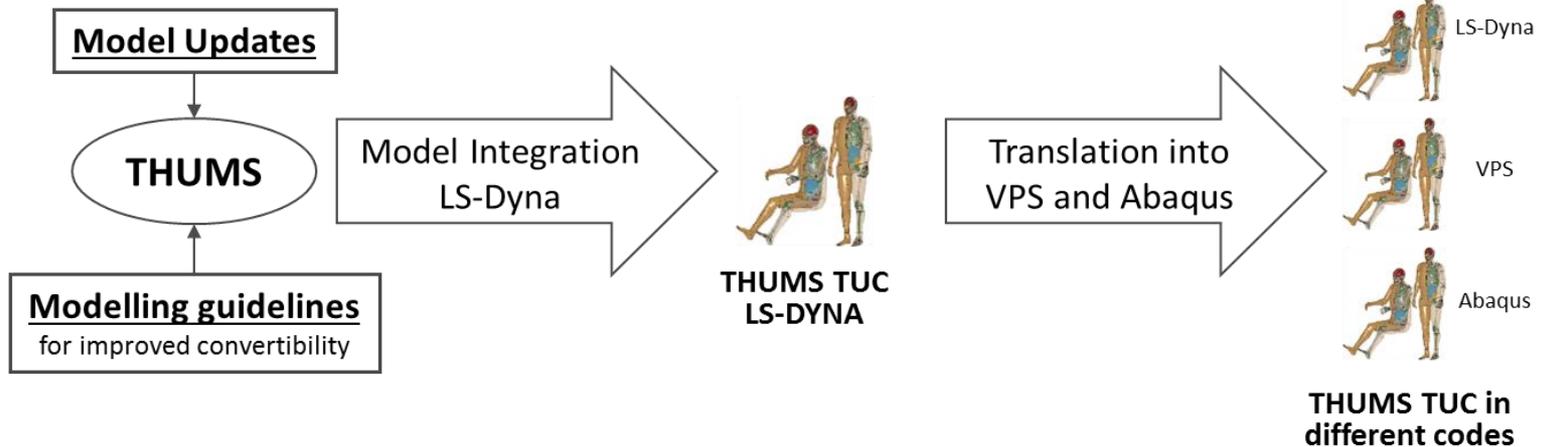
Subcontractor / Software Companies



Motivation of TUC



1. Harmonisation, provision and maintenance of a FE Human Body Model (THUMS™) in the three crash codes LS-DYNA, VPS and Abaqus
2. Development of agreed procedures for the use of Human Body Models
 - Guidelines for an improved model convertibility between codes
 - Development of validation procedures
 - Development of harmonised pre- and post-processing methods



Collaborations



CoHerent



Agenda



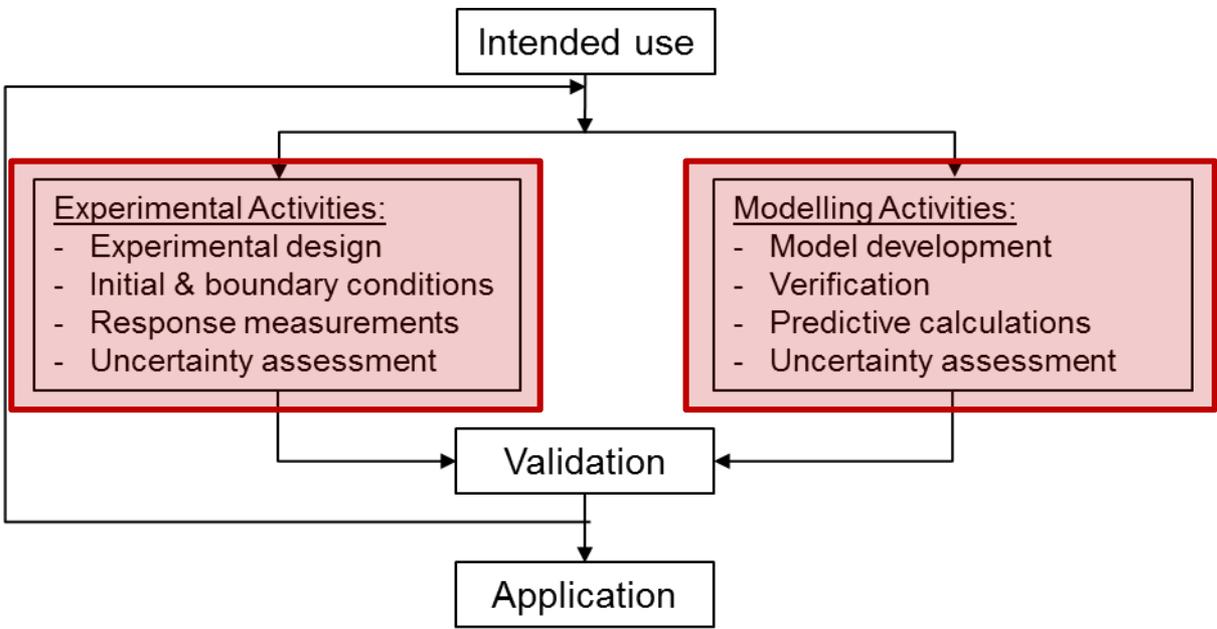
1. The THUMS User Community
2. TUC Validation Repository
3. Reference Points to standardise pre- and post-processing procedures





Motivation

“The validation should be the process where **EVIDENCE** is generated – **CREDIBILITY** is thereby established that the model has adequate accuracy and the level of detail for the intended use!” (ASME V&V 10-2006)



Challenges

- Indirect validation
- Model development and verification

Verification ≈ assessment of accuracy of computational model

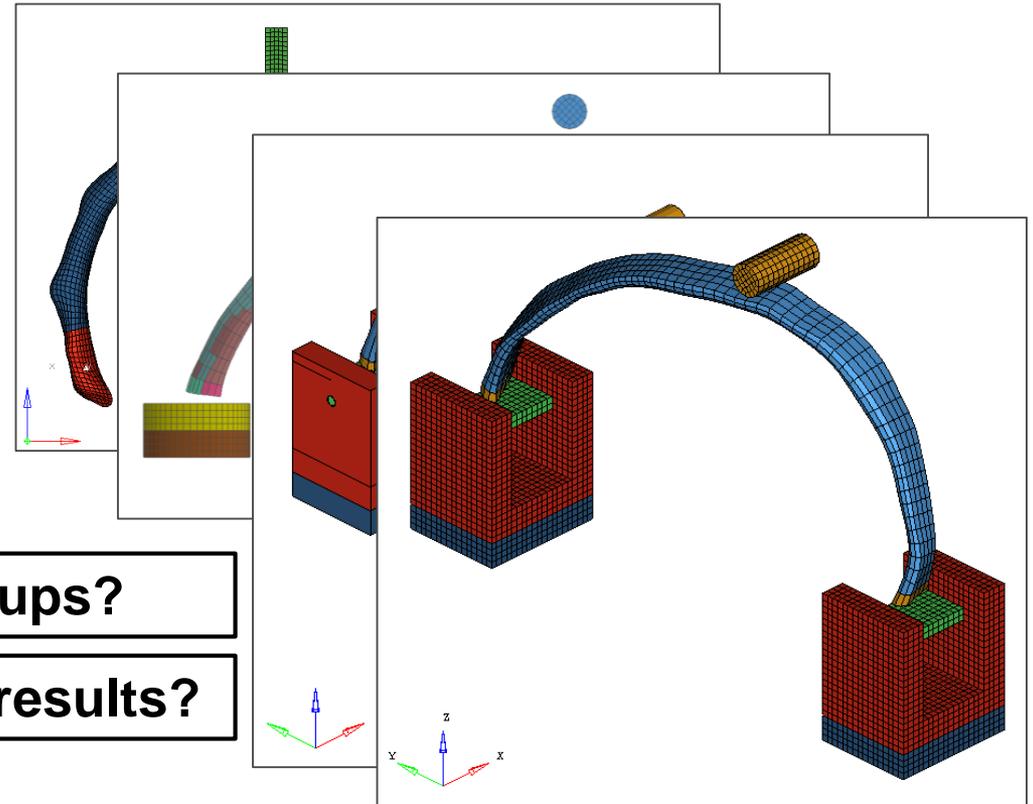
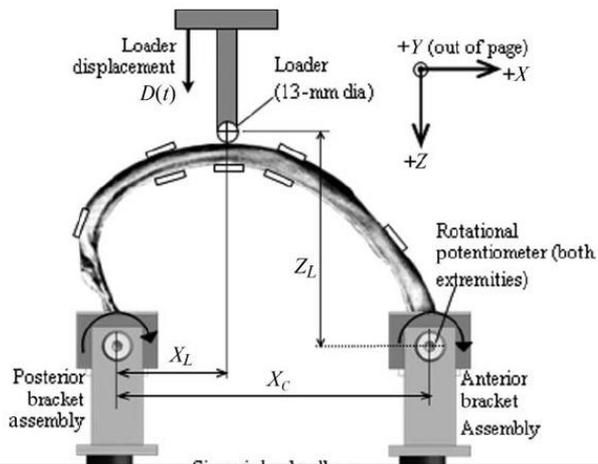
Validation ≈ assessment of the degree to which a computational model is an accurate representation of physics being modelled





Motivation

“The validation should be the process where **EVIDENCE** is generated – **CREDIBILITY** is thereby established that the model has adequate accuracy and the level of detail for the intended use!” (ASME V&V 10-2006)



Conclusion: 4 people – 4 setups?

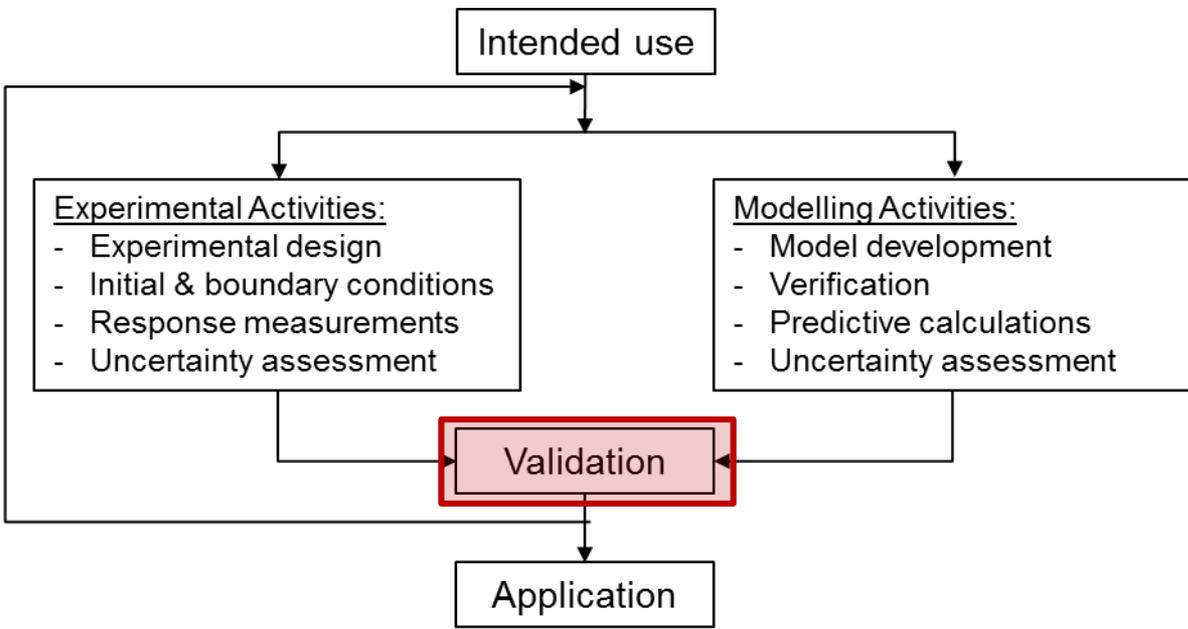
User-dependency of validation results?





Motivation

*“The validation should be the process where **EVIDENCE** is generated – **CREDIBILITY** is thereby established that the model has adequate accuracy and the level of detail for the intended use!” (ASME V&V 10-2006)*



Challenges

- Indirect validation
- Model development and verification
- Rating of validation results

Verification ≈ assessment of accuracy of computational model

Validation ≈ assessment of the degree to which a computational model is an accurate representation of physics being modelled





- ✓ Database with FE models of validation setups of state-of-the-art load cases for the validation of HBMs
- ✓ Documentation so that validation environments are consistently applied to the evaluation of HBMs

✓ Experimental

✓

✓

✓

(D)

TUC Validation Repository Validation Protocol

THUMS™ AMSO V4.01 reference:
4 rows of elements set rigid at anterior end
3 rows of elements set rigid at posterior end

b. Joints

Two revolute joints were defined at the anterior and posterior rib ends, respectively, to allow rotations about the y-axis only. The nodal coordinates of the coincident node pairs (for the anterior rib end: 1000/1001 and 1100/1101; for the posterior rib end: 2000/2001 and 2100/2101) are to be updated to meet the following specification:

- The axis of each of the two defined revolute joints is to be parallel to the y-axis of the global coordinate system.
- Based on measurements approximated from CT data, the nodes defining the axes of the revolute joints are to be chosen so that:
 - the axes are located parallel to the global y-axis,
 - they lie within a distance of 23 mm (along the rib curvature) from the rib end (cf. Figure 7) and
 - their x coordinates coincide (approximately) with the centre of each rib end.

Figure 7 Range for the position of the axis of rotation with regard to the rib end

THUMS™ AMSO V4.01 reference: nodal coordinates
 NID 1000 and 1001 (91.8149, 12.4946, 0.0)
 NID 1100 and 1101 (91.8149, -10.9962, 0.0)
 NID 2000 and 2001 (91.8149, 11.8160, 0.0)
 NID 2100 and 2101 (91.8149, -9.0215, 0.0)

4.1.3 Impactor
The impactor needs to be positioned to match the following:

THUMS User Community 12

Corridors where

Corridors in

Corridors in

Corridors in

TUC Validation Repository - Load Case Description & Validation Protocol

Thorax: Isolated Rib under Lateral Loading

Version:

V04

LS-Dyna version provided by:

University of Munich (LMU)

Last updated:

August 18, 2016

Experimental data provided by:

Jason Forman, University of Virginia

Contact Person:

Therese Fuchs, Biomechanics Group, University of Munich (LMU)
therese.fuchs@med.uni-muenchen.de



Benefits

- ✓ User independence: Minimisation of manual manipulation or user's judgment during initial positioning/ settling with gravity
 - Consistent execution requires a precise and detailed documentation with step-by-step instructions for the pre- and post-processing procedure
 - Documentation so that validation environments are consistently applied to the evaluation of HBMs
- ✓ Model independence
- ✓ Crash code independence

Remaining challenges

- ✓ Modelling level dependence: classification of validation parameters





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TUC Validation Repository

Available Load Cases

- **Thorax - Lateral Rib Bending** in cooperation with University of Virginia

General Information

A substantial validation is fundamental to establish credibility in HBMs. However, agreed methods for a user-independent objective validation are missing. The standardisation of such methods presents a great challenge. The setup of most validation load cases require manual manipulation or user's judgement during initial positioning and are therefore highly subjective. Depending on the load case, some validation environments also require initial settling of the HBM with gravity, followed by exporting the settled geometry to set as the initial position. Consistent execution of these steps requires precise and detailed documentation with step-by-step instructions for the validation environment setup and analysis. The TUC Validation Repository is being developed to provide standardised validation environments and protocols to the HBM community. The Repository is planned to consist of validation kits of state-of-the-art load cases. Each kit comes with the FE model of the validation environment in different crash codes (Abaqus, LS-Dyna, Radioss and VPS), validation parameters in terms of response corridors and a detailed code-dependent protocol of how to use the data for the application of an HBM.

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Validation Kits

Code	Version	Last update	Remarks
Abaqus	-	coming soon	provided by University of Munich (LMU) (Contact: therese.fuchs@med.lmu.de)
LS-Dyna	V01	Oct. 2016	provided by University of Munich (LMU) (Contact: therese.fuchs@med.lmu.de)
Radioss	-	coming soon	not yet available
VPS	V01	Oct. 2016	provided by University of Munich (LMU) (Contact: therese.fuchs@med.lmu.de)

General Information about Load Case

Body region	Thorax
Level	Component
Load case	Dynamic lateral loading of isolated rib
References	Experiments published in: <i>E del Pozo, M Kinding, C Arregui-Dalmases, J Crandall, S Takayama, S Ejima, K Kamiiji, T Yasuki (2011), Structural response and strain patterns of isolated ribs under lateral loading. International Journal of Crashworthiness, Vol 16, No. 2, pp. 169-180.</i>
Unit system	kg - mm - ms - kN - GPa
Codes	Abaqus (coming soon) LS-Dyna Radioss (not yet available) VPS
Experimental data provided by	Jason Forman, University of Virginia
Contact	Therese Fuchs Biomechanics Group University of Munich (LMU) therese.fuchs@med.lmu.de

www.tuc-project.org/validation-repository



Outlook

- Gold standard validation environment to be published in 2016
- Experimental data provided by University of Virginia
- Further validation environments to be published within **follow-up project**



www.tuc-project.org/validation-repository



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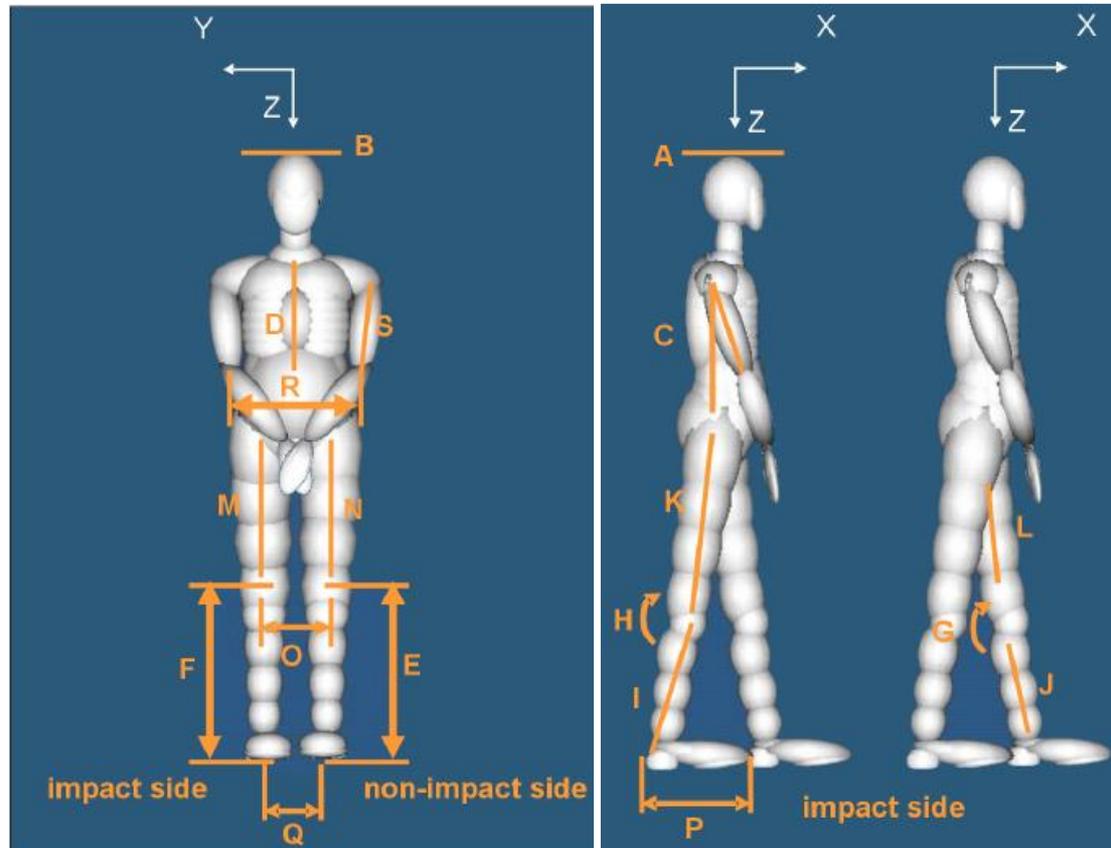


Why Reference Points?

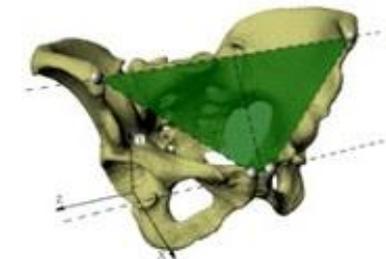
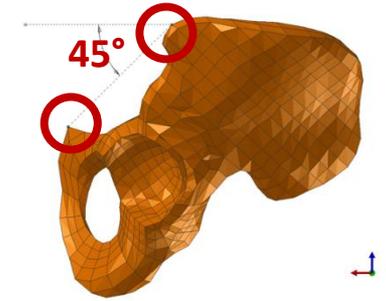
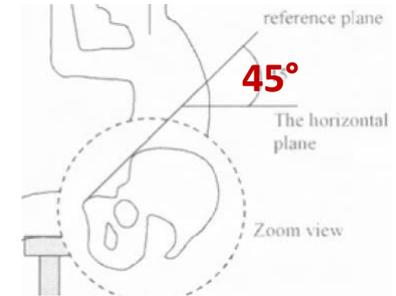
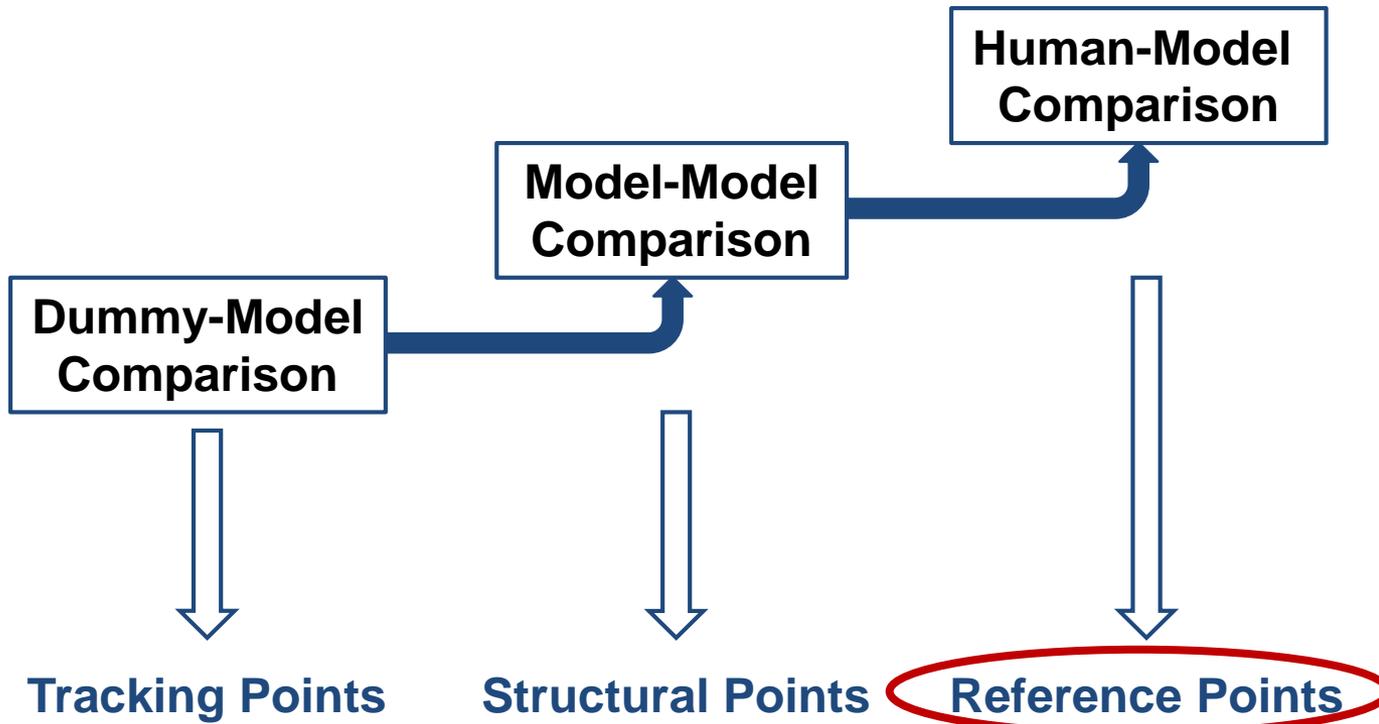


SAE J2782

- A: Angle of X axis of head accelerometer
- B: Angle of Y axis of head accelerometer
- C: Angle of thoracic spine about Y axis
- D: Angle of thoracic spine about X axis
- E: Vertical height from ground to non-impact knee joint center
- F: Vertical height from ground to impact knee joint center
- G: Angle between non-impact femur and thigh
- H: Angle between impact femur and thigh
- I: Impact tibia angle about Y axis
- J: Non-impact tibia angle about Y axis
- K: Impact femur angle about Y axis
- L: Non-impact femur angle about Y axis
- M: Impact femur angle about X axis
- N: Non-impact femur angle about X axis
- O: Distance in Y direction between knee joint centers
- P: Heel to heel distance in the X axis
- Q: Distance in Y direction between heel points
- R: Distance in Y direction between elbow joint centers
- S: Angle of upper arm about X axis



Why Reference Points?



Why Reference Points?

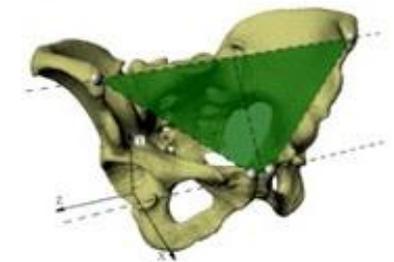
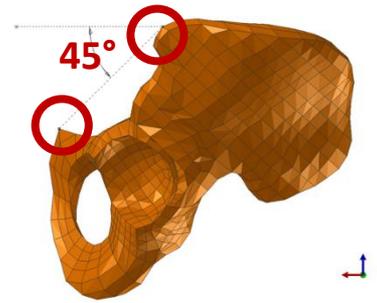
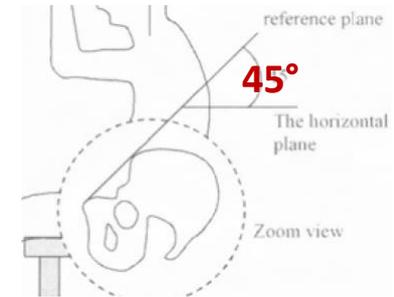


Definition of anatomically meaningful postures of pedestrians and occupants

- Comparability between HBMs and real human beings
- Building a kinematic chain for positioning
- Identifiably on FE models and human beings (CT/MRI/palpable)
- Re-meshing resistant

- Geometrically calculated points
- Joint rotation centres / axes
- Bony landmarks

- Long term – to be defined once for each HBM



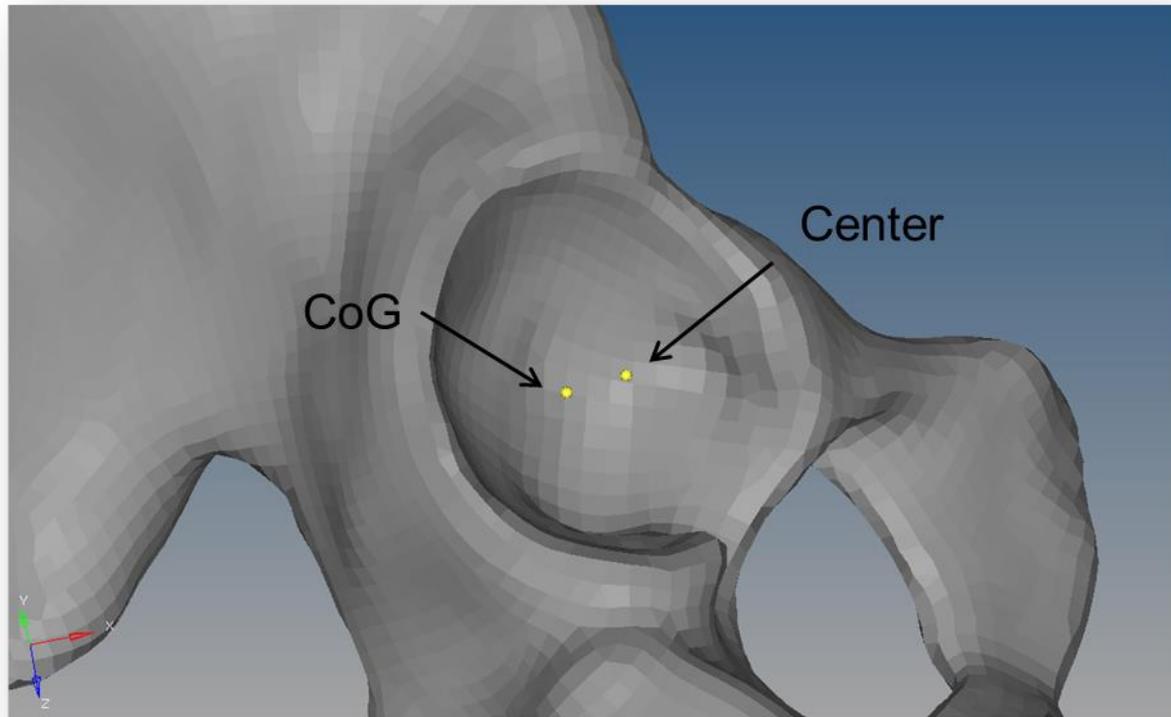
Center = the point equidistant from the points on the surface

VS.

Centroid = arithmetic mean, “average” position of all points on the object’s surface
(\approx center of gravity if mass is equally distributed)

Why **Center** and not Center of Gravity?

→ Calculable on FE-Models
and human beings
(CT/MRI)



1. Functional Reference Points

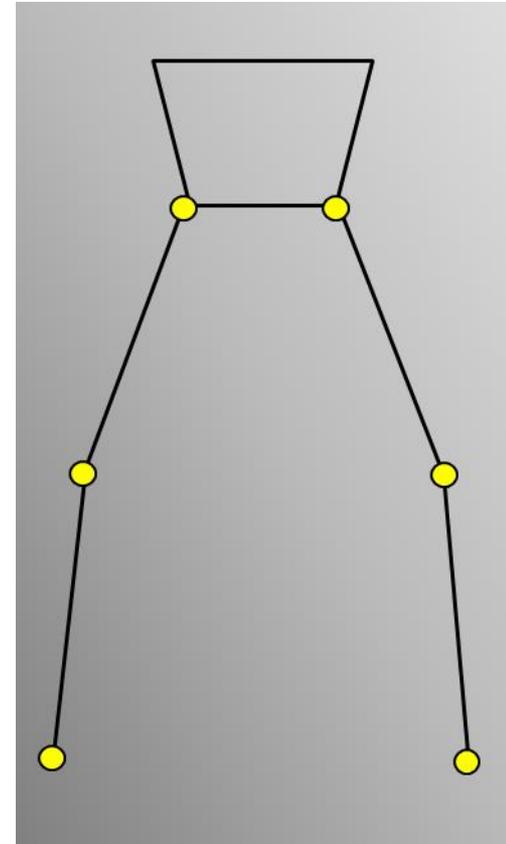
- Building a kinematic chain for pedestrian/occupant positioning
- Defining angles and distances to non-ambiguously describe the position of the pedestrian/occupant in the global coordinate system

2. Technical Reference Points

- Need to be defined for the determination of Functional Points

3. Anatomical Reference Points

- Bony landmarks
- Points describing e.g. Pelvic Plane, Frankfurt Plane



Reference Points



HIP Points



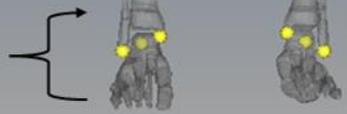
- Acetabulum
- H-Point
- Pubic tubercles
- ASIS

KNEE Points

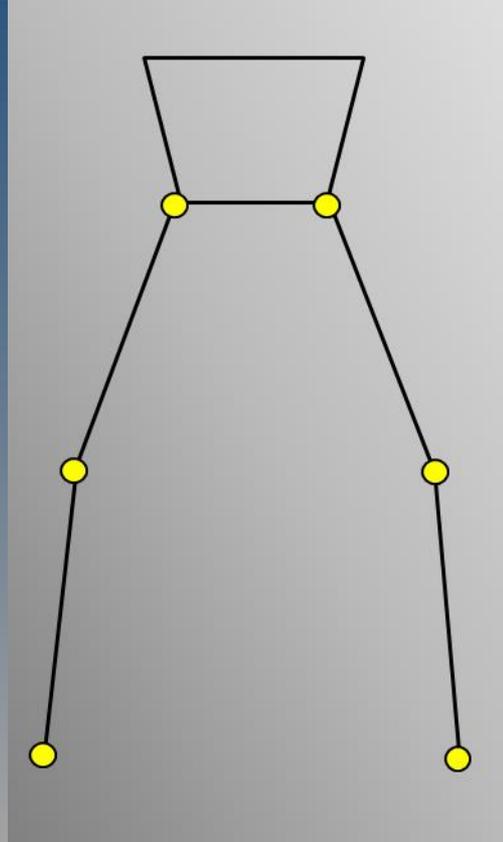
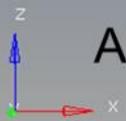


- Inner Knee Point
- Outer Knee Point
- Knee Point

ANKLE Points



- Inner Ankle Point
- Outer Ankle Point
- Ankle Point



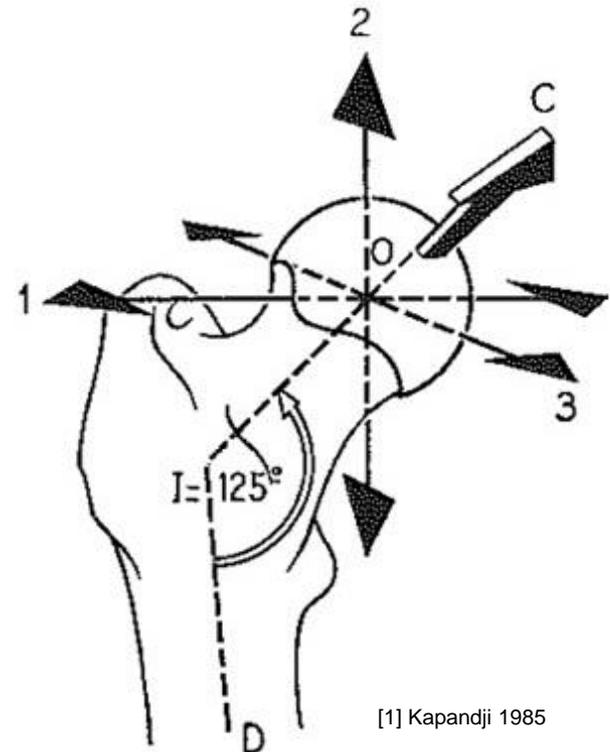
Reference Points: Example HIP



Note: The definition of joint centers is non-ambiguous in the hip!

Acetabulo femoral joint

- Synovial ball-and-socket joint^[1]
- Formed between the os coxa and the femur
- The femoral head represents 2/3 of a boule with a diameter of 40 - 50 mm^[1]
- The hip joint center is located in the center of the femoral head^[2]
- The collo-diaphyseal angle which is the inclination angle between the femoral shaft and neck is 125° in adults^[1]



[1] Kapandji 1985





Acetabulum

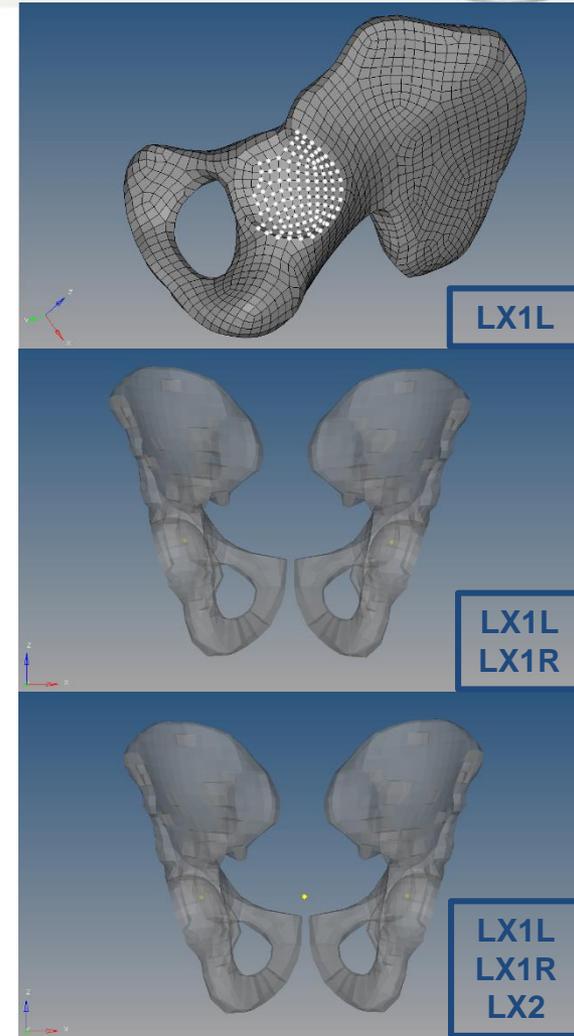
Define the *Center* of the acetabulum on the left and right hip bone.

- Select all nodes which belong to the hemi-sphere's surface
 - ✓ LX1R
 - ✓ LX1L

H-Point

The H-Point is the midpoint of the left and right Acetabulum points (LX1R and LX1L).

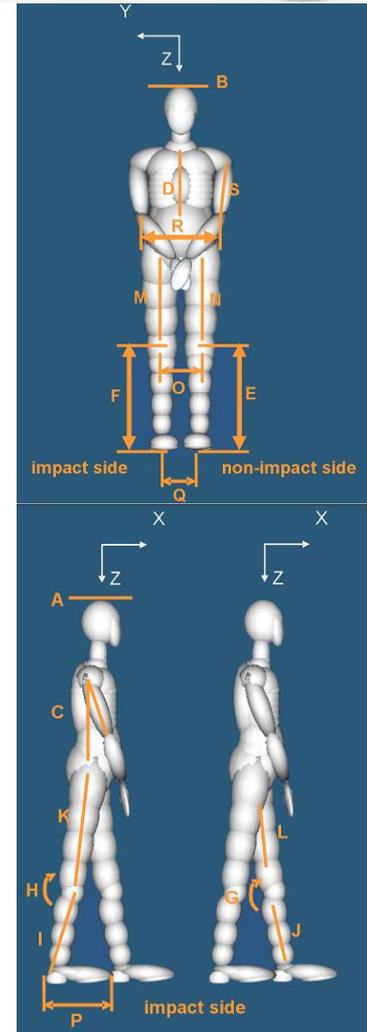
- ✓ LX2



Why Reference Points?



SAE Norm		Reference Point	
G H	Knee Bend Angle	LX1 LX3 LX4	Angle Hip-/Knee-/Ankle Point
E F	Knee Height	LX3 LX8	Distance Knee-/Heel Point
O	Knee to Knee Width	LX3R LX3L	Distance Knee Point left leg/right leg
P Q	Heel to Heel Distance	LX8R LX8L	Distance Heel Point left leg/right leg



Reference Points: Limitations



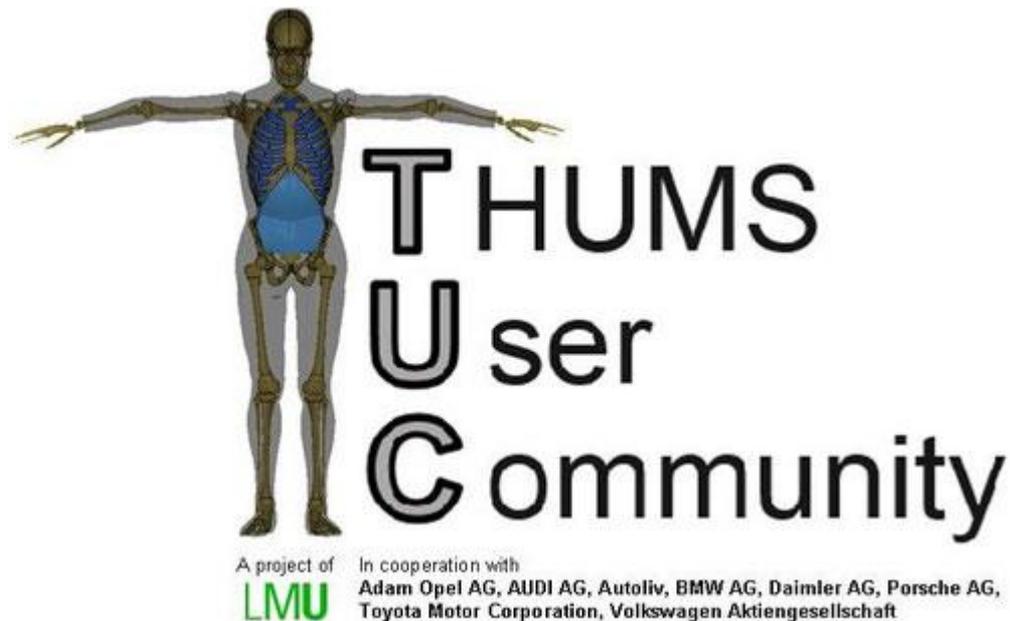
1. The specific assignment of nodes to the hemisphere's surface during the determination of the **Acetabulum Point** and **Knee Point**
2. The visualization of the most distal/anterior etc. points in a 3D human model e.g. during the determination of the **Inner** and **Outer Ankle Point**



Acknowledgment



Web link: www.TUC-project.org



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THANK YOU!

