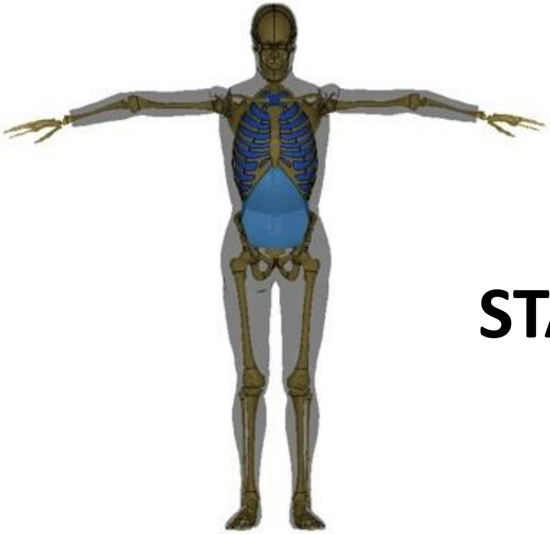


THUMS USER COMMUNITY – STANDARDISING THE APPLICATION OF HUMAN BODY MODELS

Therese Fuchs[1], Matthias Erzgraeber[2], Franz Fuerst[3], Christian Mayer[4], Bengt Pipkorn[5], Philipp Wernicke[6], Tsuyoshi Yasuki[7], Steffen Peldschus[1,8]

[1] University of Munich, Germany, [2] Adam Opel AG, Germany [3] AUDI AG, Germany, [4] Daimler AG, Germany, [5] Autoliv, Sweden, [6] BMW AG, Germany, [7] Toyota Motor Corporation, Japan, [8] Hochschule Furtwangen University, Germany

Mannheim, 29th of November, 2016

Agenda

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

THUMS User Community (TUC)

Core Partners

Audi
Autoliv
BMW
DAIMLER
OPEL
PORSCHE
TOYOTA
VOLKSWAGEN AKTIENGESELLSCHAFT

Associated Partners

AGU Zürich
bast
IAT
pdb PARTNERSHIP FOR DUMMY TECHNOLOGY AND BIOMECHANICS
UNIVERSITÉ DE STRASBOURG
virtual vehicle

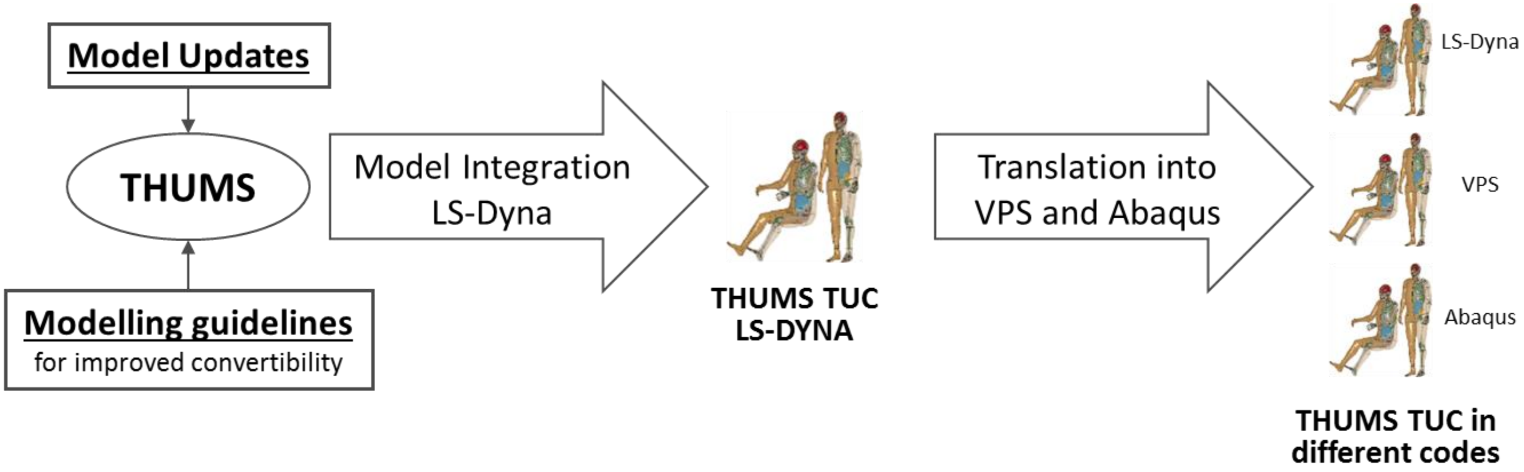
Subcontractor / Software Companies

DYNA MORE
esi get it right®

Motivation of TUC

1. Harmonisation, provision and maintenance of a FE Human Body Model (THUMS^{TM}) 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

PIPER

SENIORS

UNIVERSITY of VIRGINIA
CENTER FOR APPLIED BIOMECHANICS

CoHerent

Agenda

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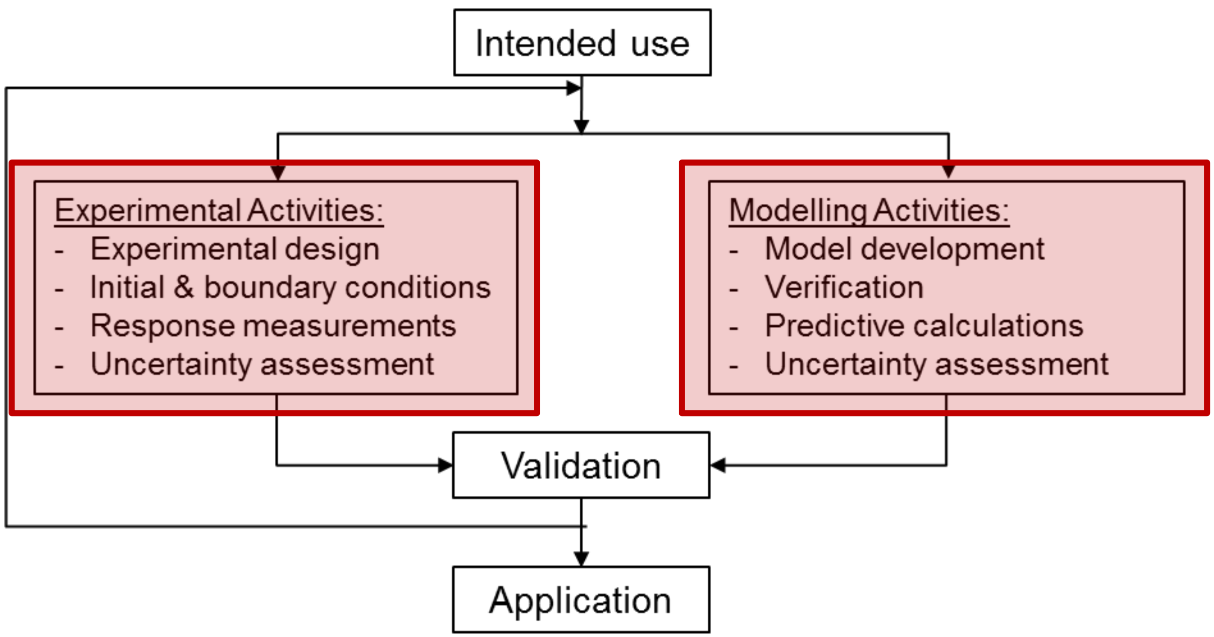
3. Reference Points to standardise pre- and post-processing procedures

TUC Validation Repository

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

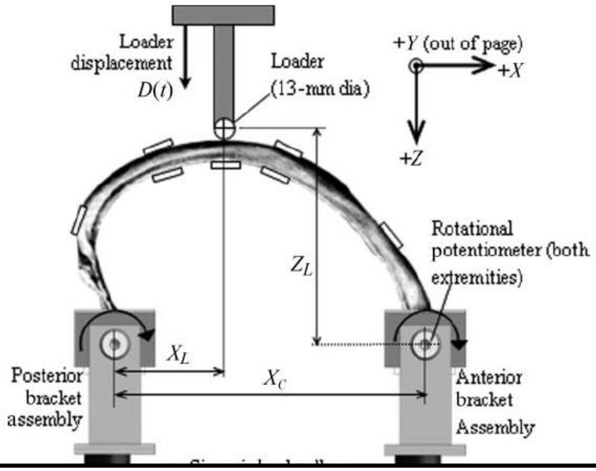
Verification ≈ assessment of accuracy of computational model

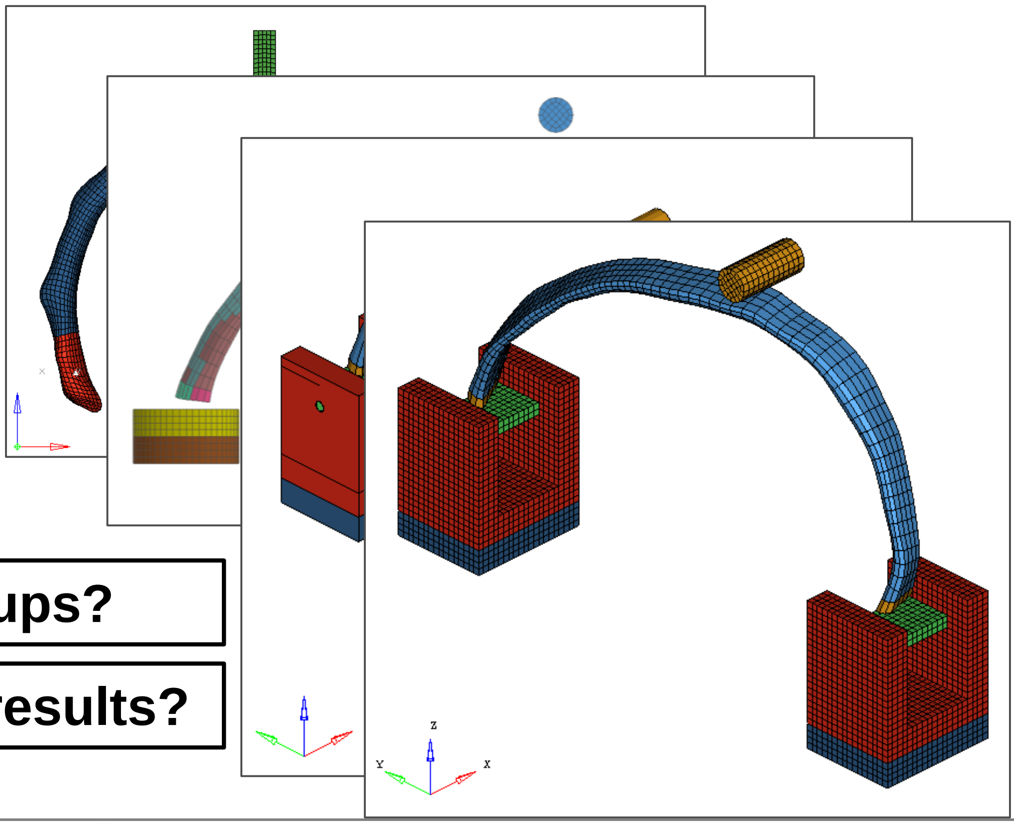
Validation ≈ assessment of the degree to which a computational model is an accurate representation of physics being modelled

TUC Validation Repository

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)***





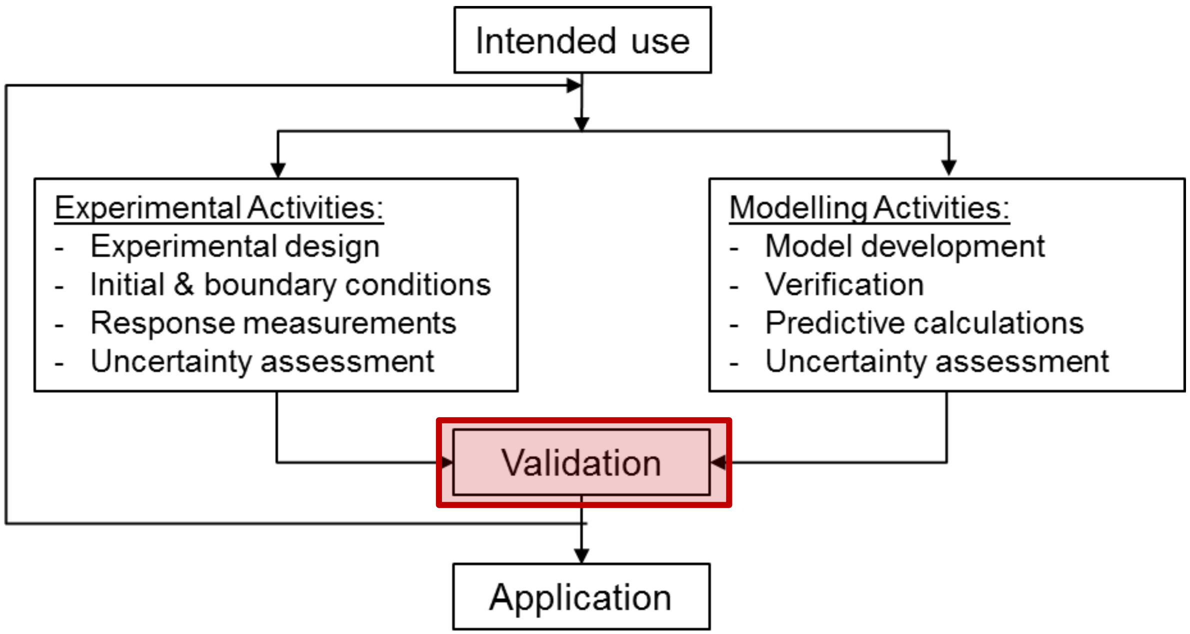
Conclusion: 4 people – 4 setups?

User-dependency of validation results?

TUC Validation Repository

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)***



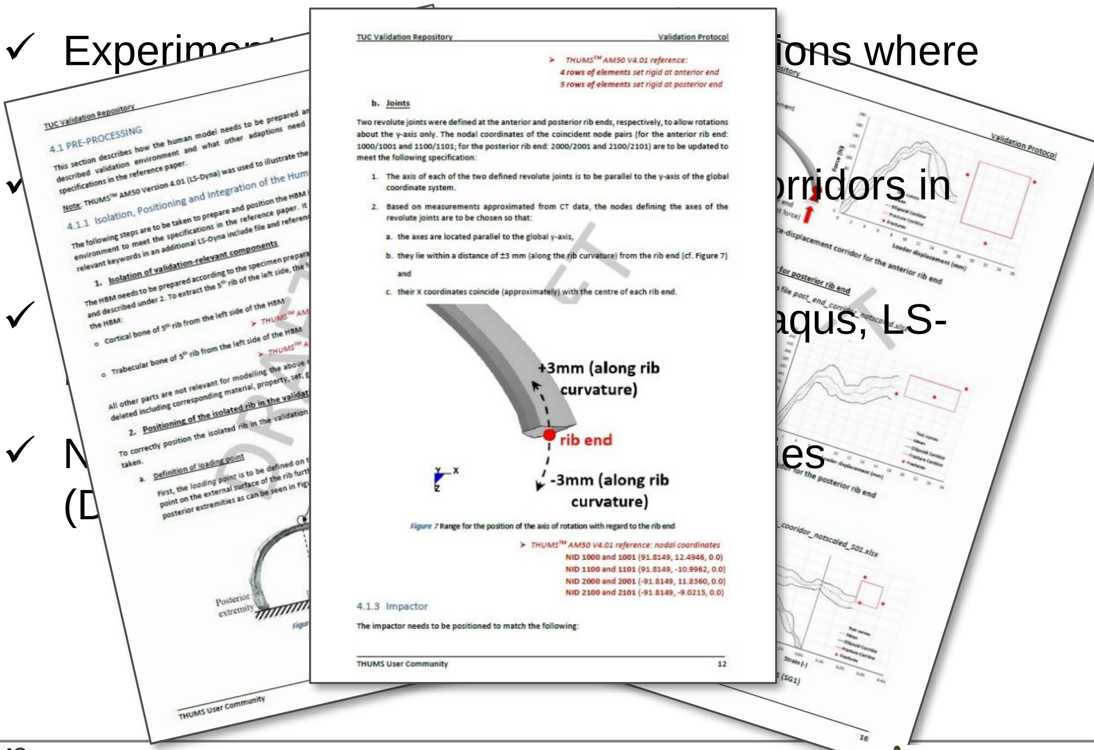
Challenges

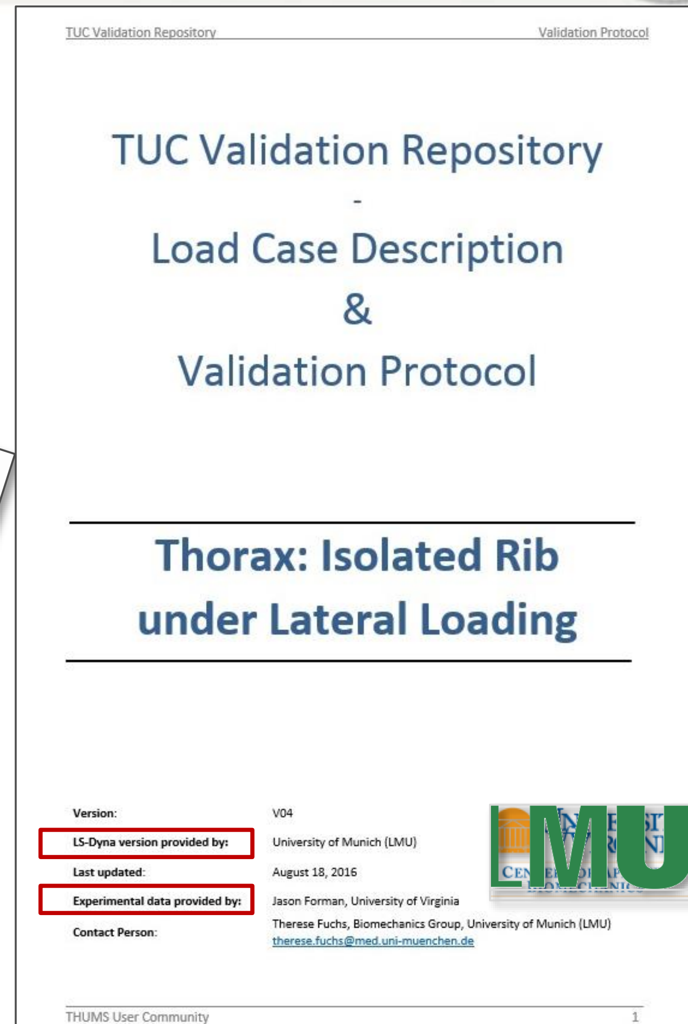
- Indirect validation
- Model development and verification
- Rating of validation results

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

TUC Validation Repository

- ✓ 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
- ✓ Experim… …ions where
- ✓ …rridors in
- ✓ …aqus, LS-
- ✓ N… …es (D…





TUC Validation Repository

Benefits

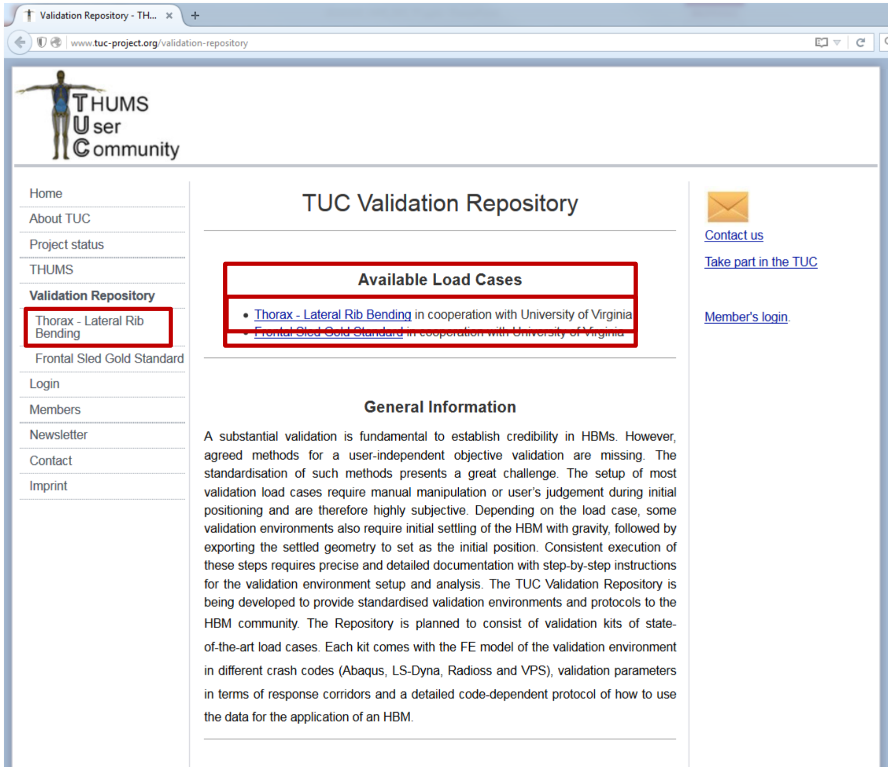
- ✓ User independence: Minimisation of manual manipulation or user's judgment during initial positioning/ settling with gravity
  - → Consistent execution requires a precise and detailed documentation with step-by-step instructions for the pre- and post-processing procedure
  - → Documentation so that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

Remaining challenges

- ✓ Modelling level dependence: classification of validation parameters

TUC Validation Repository

LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN



Validation Repository - TH...

www.tuc-project.org/validation-repository

THUMS User Community

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- THUMS
- **Validation Repository**
  - Thorax - Lateral Rib Bending
  - Frontal Sled Gold Standard
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TUC Validation Repository

Available Load Cases

- Thorax - Lateral Rib Bending in cooperation with University of Virginia
- Frontal Sled Gold Standard in cooperation with University of Virginia

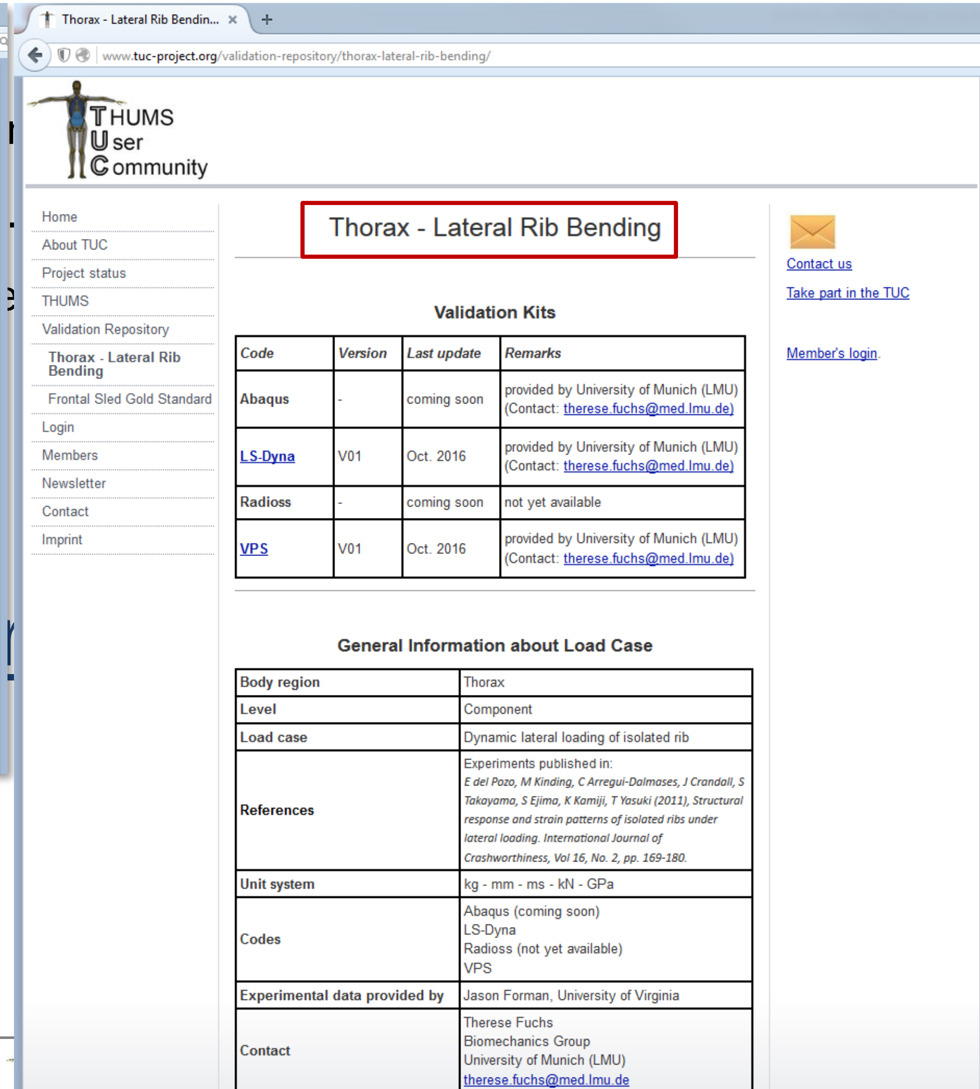
General Information

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.

Contact us

Take part in the TUC

Member's login.



Thorax - Lateral Rib Bendin...

www.tuc-project.org/validation-repository/thorax-lateral-rib-bending/

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Thorax - Lateral Rib Bending

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: *E del Pozo, M Kinding, C Arregui-Dalmases, J Crandall, S Takayama, S Ejima, K Kamiji, 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.*
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

Contact us

Take part in the TUC

Member's login.

www.tuc-project.org/validation-repository

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

TUC Validation Repository

Outlook

→ Gold standard validation environment to be published in 2016

→ Experimental data provided by University of Virginia

University of Virginia Center for Applied Biomechanics

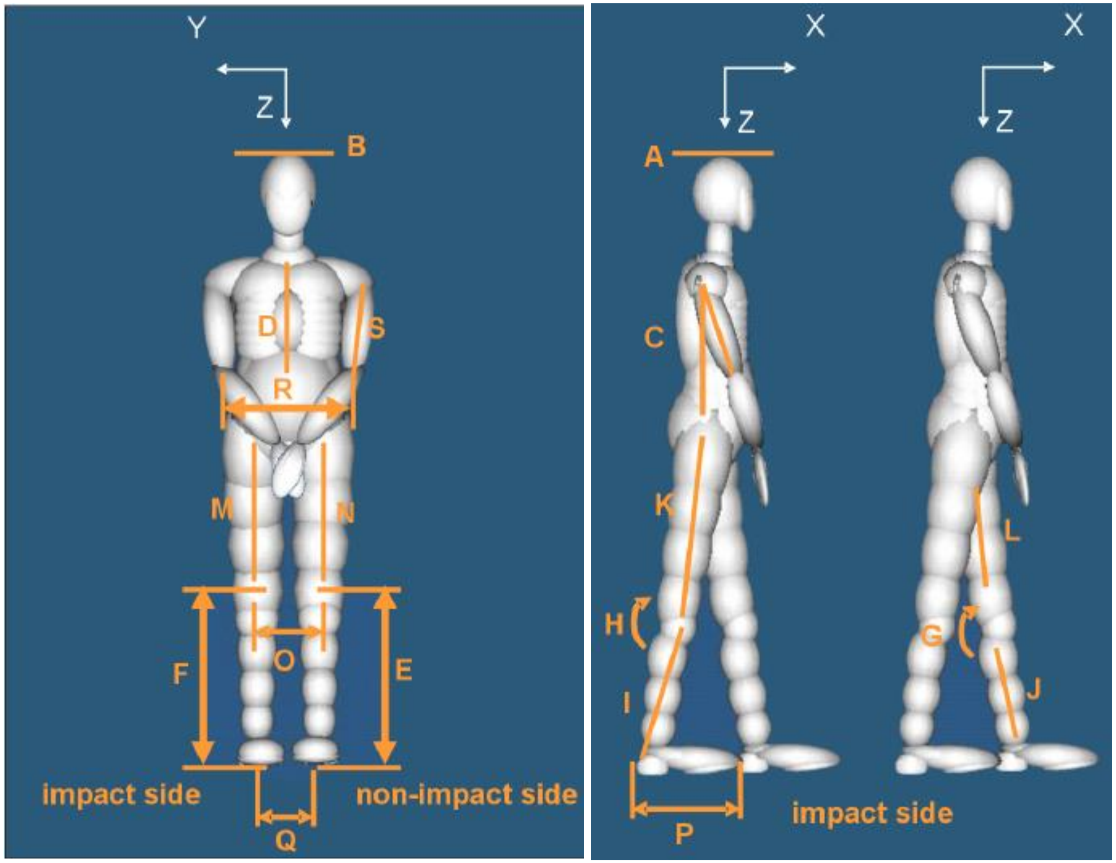
→ Further validation environments to be published within **follow-up project**

www.tuc-project.org/validation-repository

Agenda

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

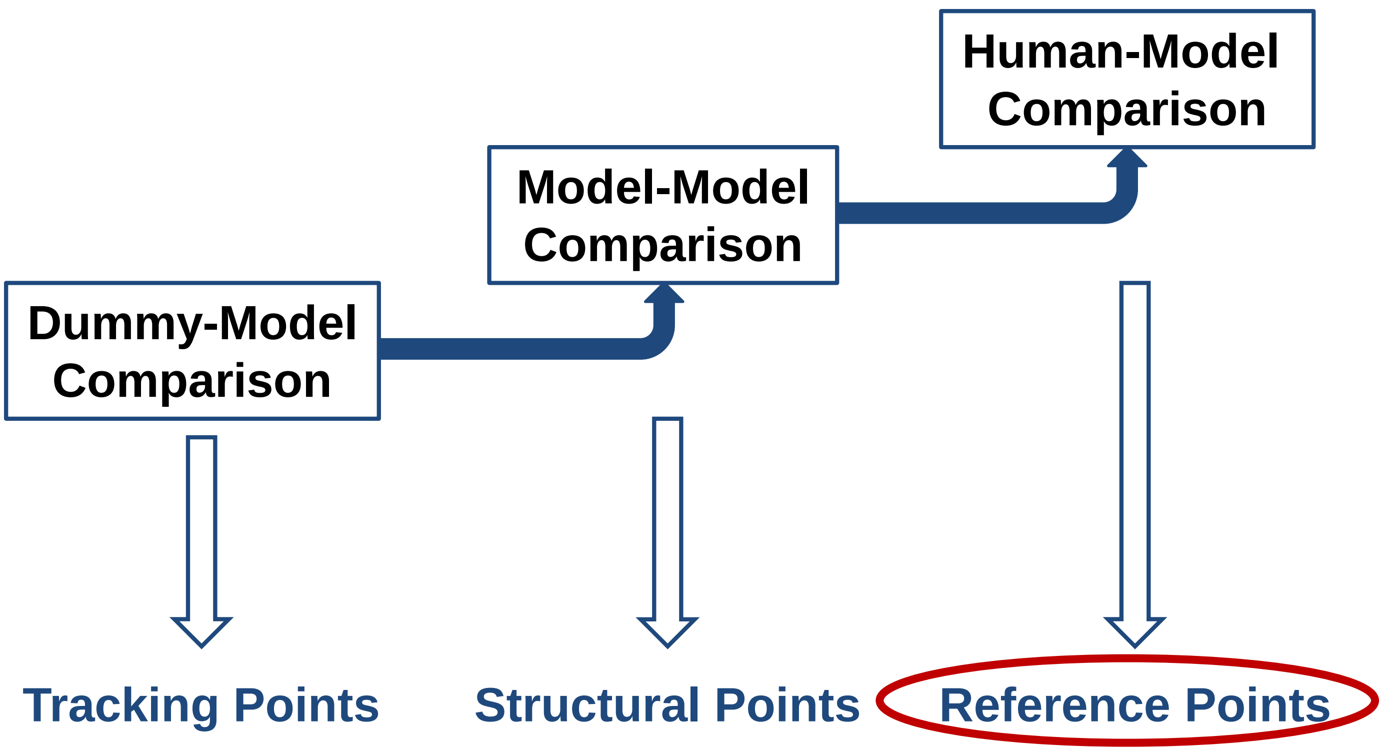
Why Reference Points?

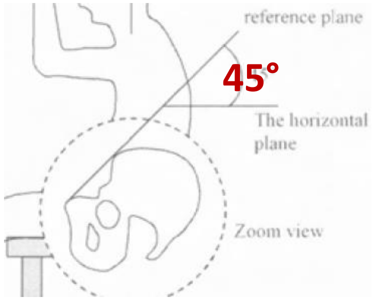


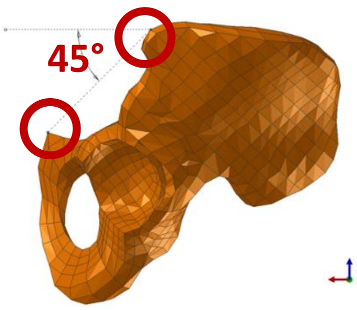
SAE J2782

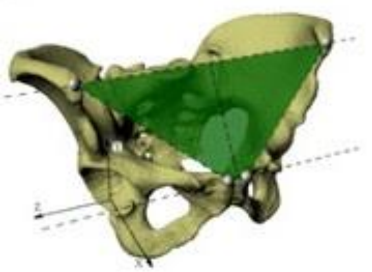
A: Angle of X axis of head accelerometer
B: Angle of Y axis of head accelerometer
C: Angle of thoracic spine about Y axis
D: Angle of thoracic spine about X axis
E: Vertical height from ground to non-impact knee joint center
F: Vertical height from ground to impact knee joint center
G: Angle between 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?









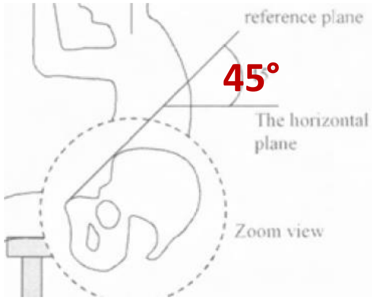
Why Reference Points?

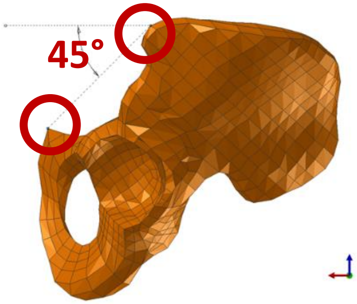
Definition of anatomically meaningful postures of pedestrians and occupants

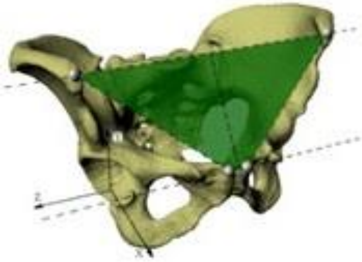
- Comparability between HBMs and real human beings
- Building a kinematic chain for positioning
- Identifiably on FE models and human beings (CT/MRI/palpable)
- Re-meshing resistant

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

- Long term – to be defined once for each HBM







Reference Points

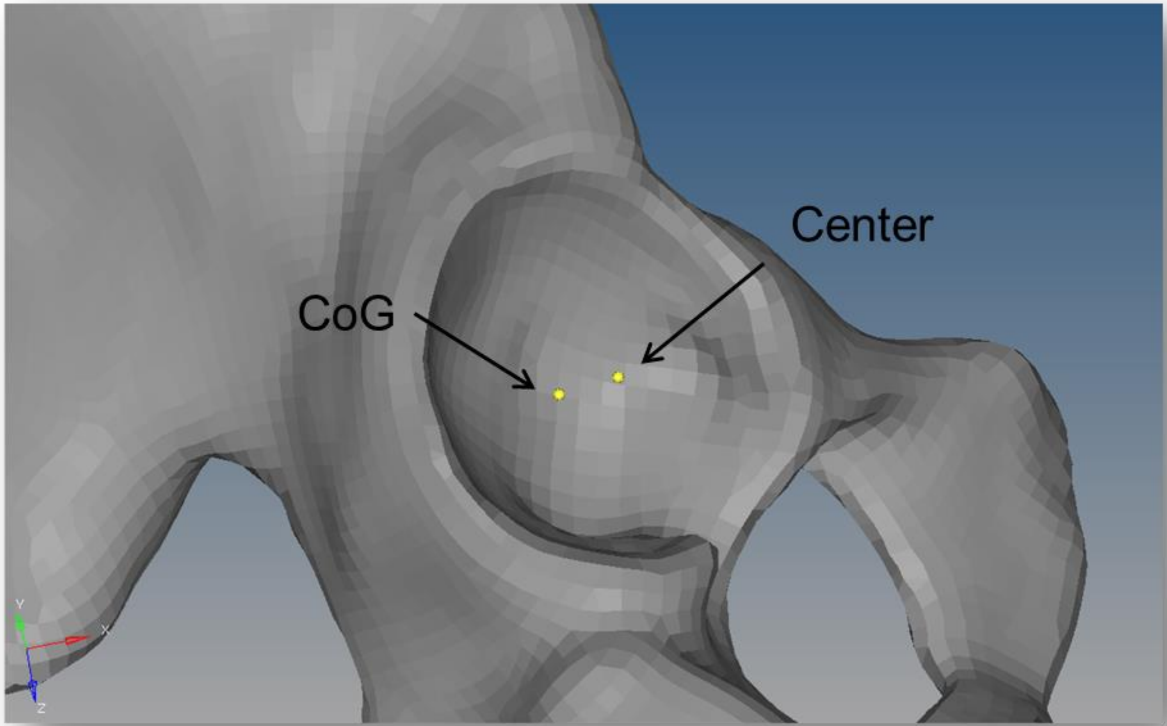
Center = the point equidistant from the points on the surface

vs.

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

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

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

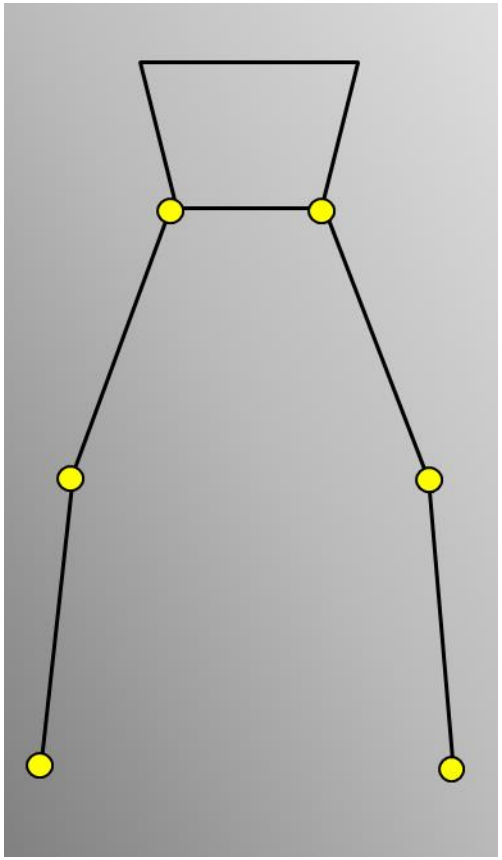


Reference Points

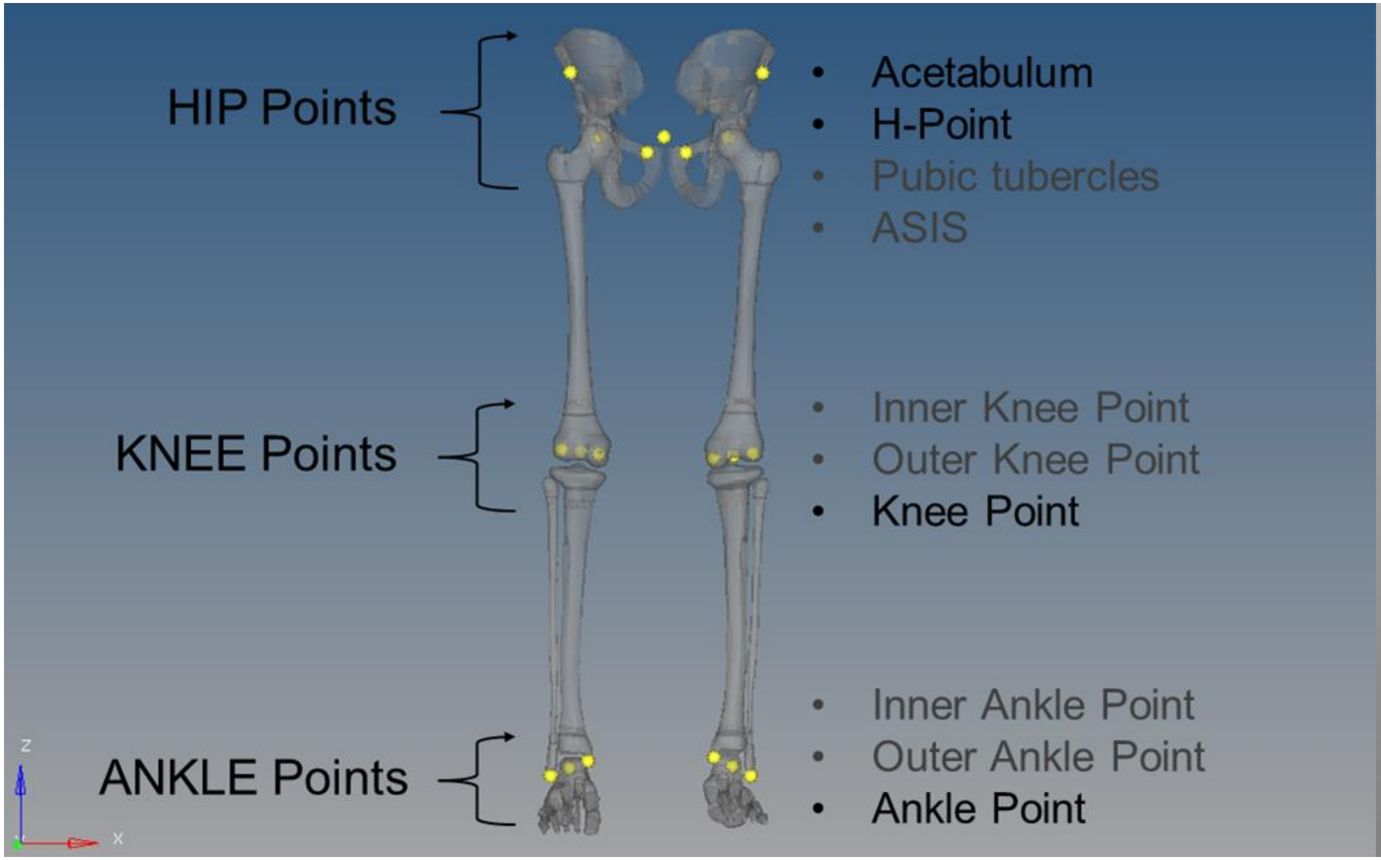
1. **Functional Reference Points**
   - Building a kinematic chain for pedestrian/occupant positioning
   - Defining angles and distances to non-ambiguously describe the position of the pedestrian/occupant in the global coordinate system

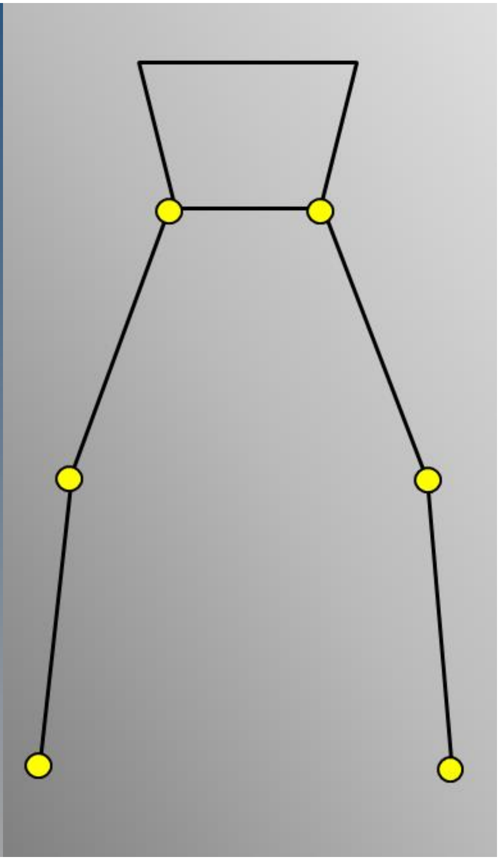
2. **Technical Reference Points**
   - Need to be defined for the determination of Functional Points

3. **Anatomical Reference Points**
   - Bony landmarks
   - Points describing e.g. Pelvic Plane, Frankfurt Plane



Reference Points



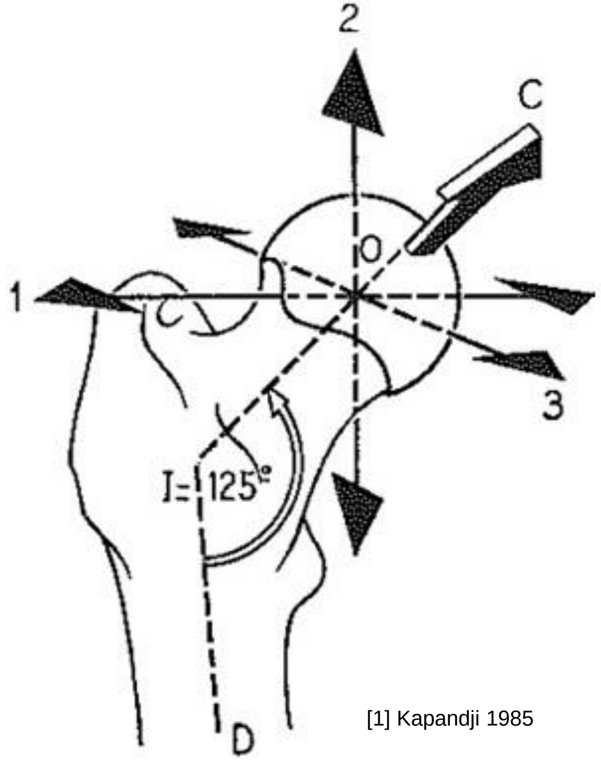


Reference Points: Example HIP

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

Reference Points: Example HIP

Acetabulum

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

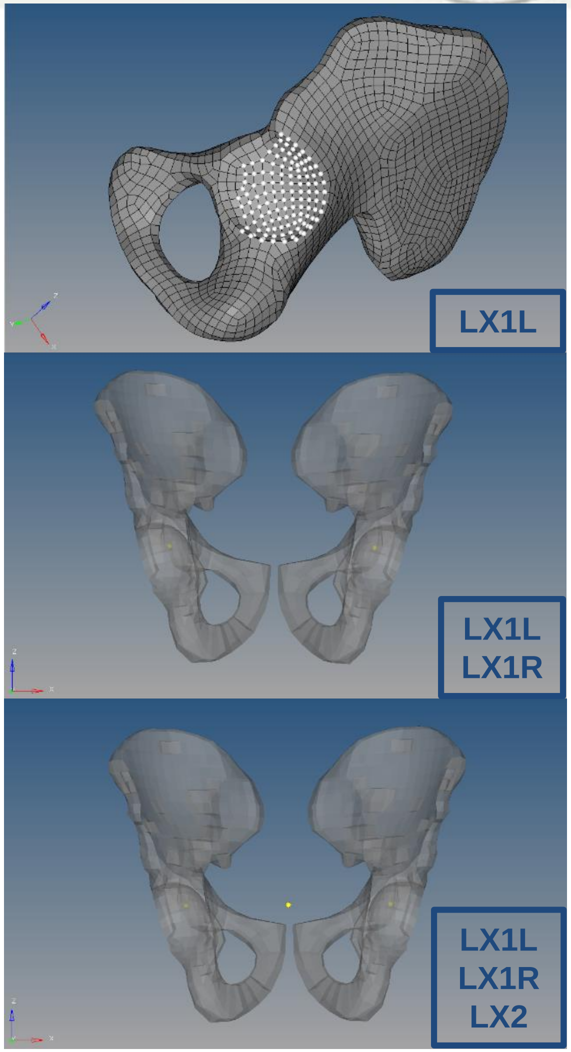
- Select all nodes which belong to the hemi-sphere´s surface

  ✓ **LX1R**
  ✓ **LX1L**

H-Point

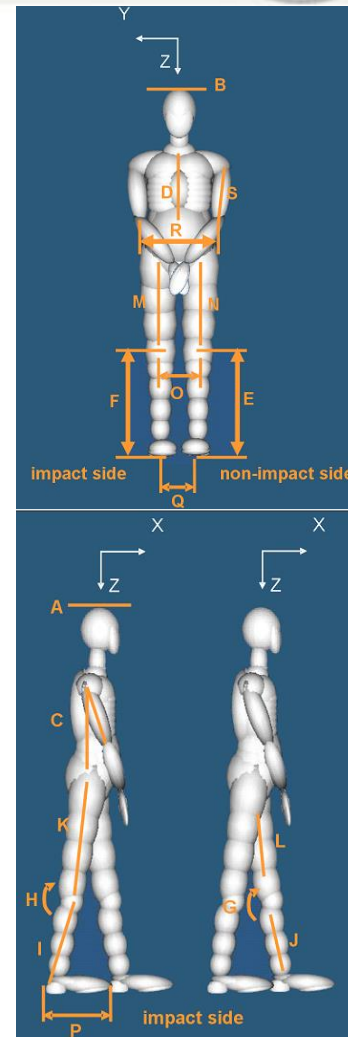
The H-Point is the midpoint of the left and right Acetabulum points (LX1R and LX1L).

  ✓ **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



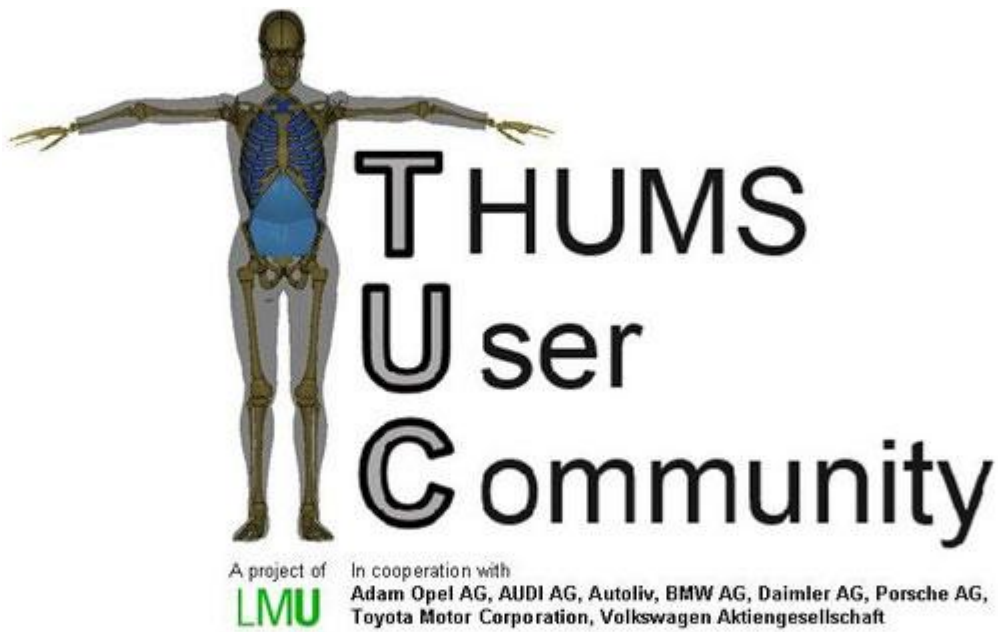
Reference Points: Limitations

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



The work presented has been conducted by **THUMS User Community**, a project of LMU in cooperation with Adam Opel AG, AUDI AG, Autoliv, BMW AG, Daimler AG, Dr. Ing. h.c.F. Porsche AG, Toyota Motor Corporation & Volkswagen Aktiengesellschaft.

THANK YOU!