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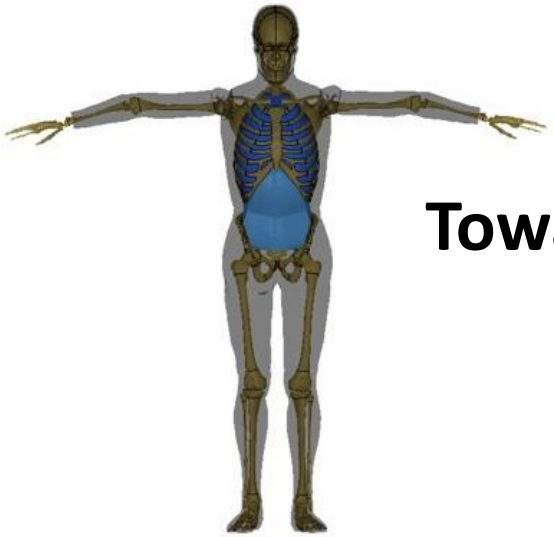

Towards a More Standardized Application of Human Body Models

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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

THUMS User Community (TUC)

Core Partners

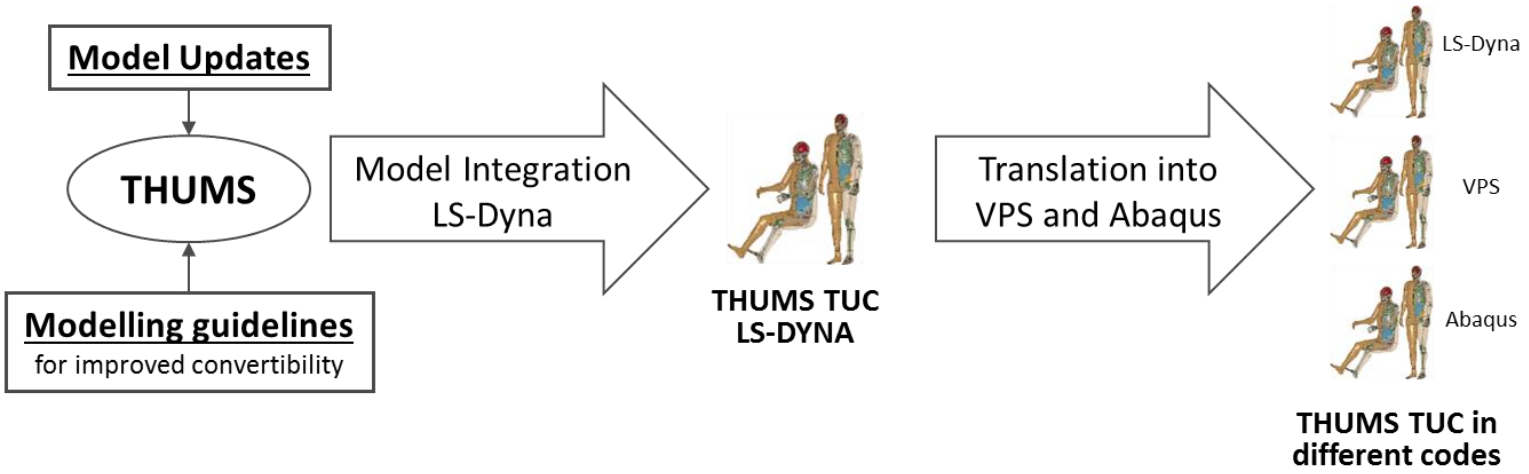
Associated Partners

Subcontractor / Software Companies

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

CoHerent

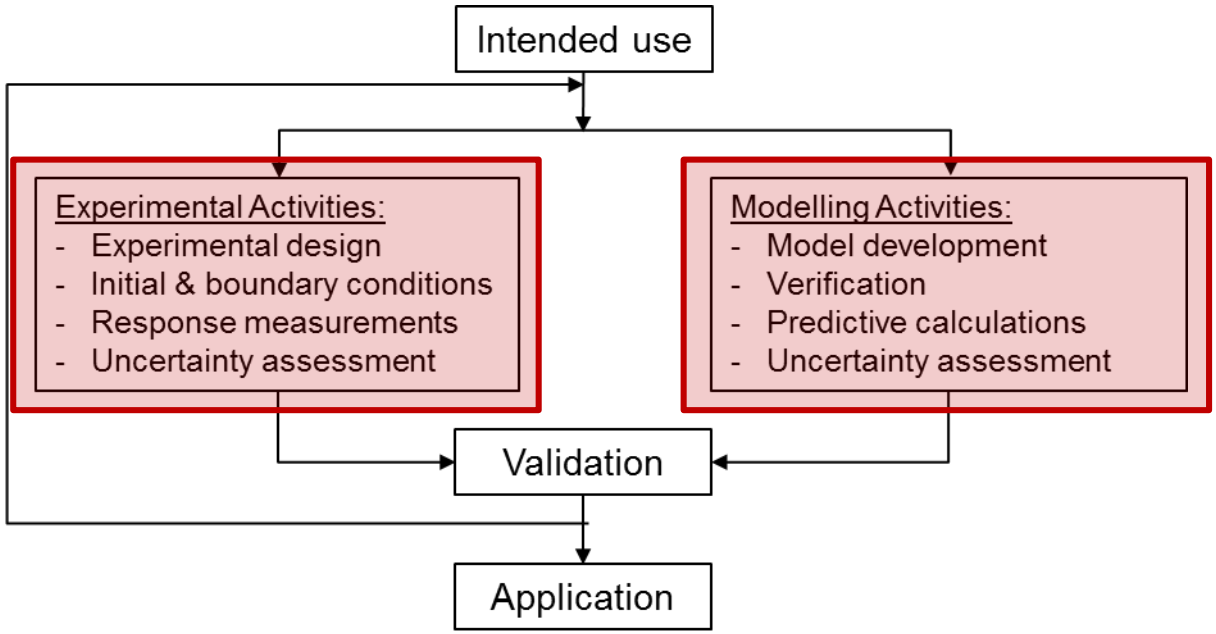
Agenda

1. The THUMS User Community
2. TUC Validation Repository
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

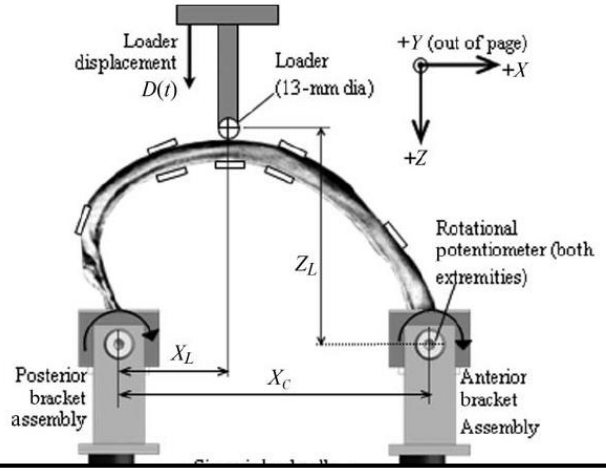
- Indirect validation
- Model development and verification

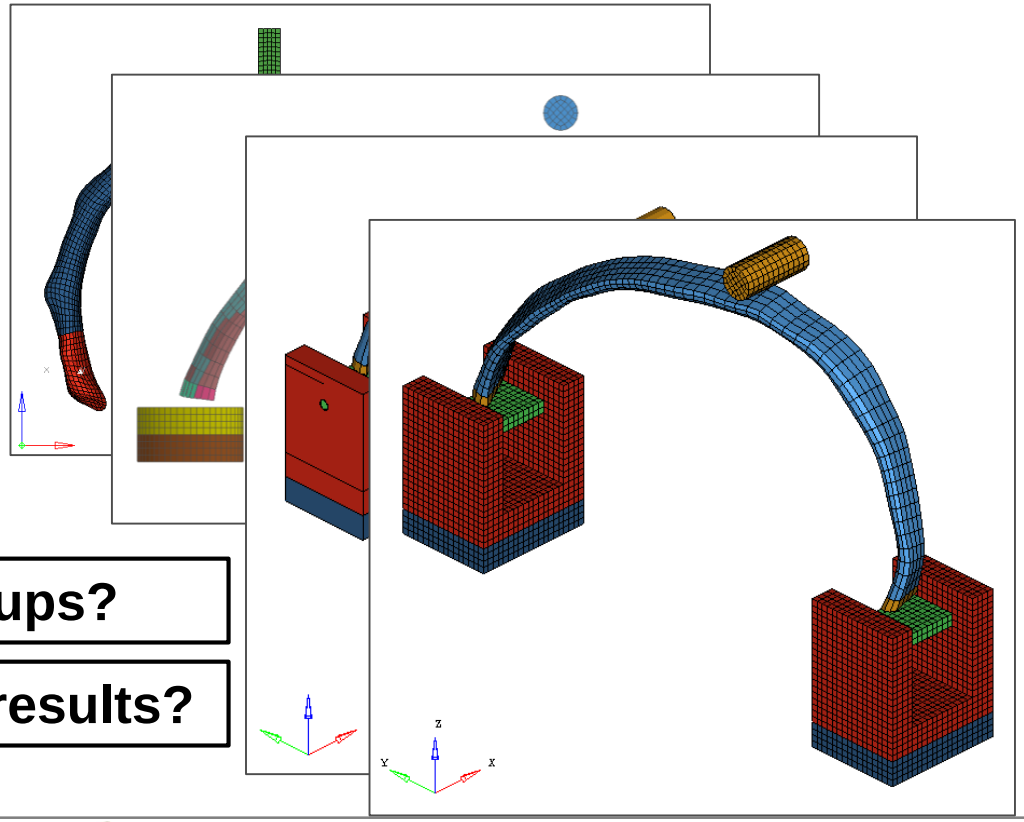
Verification ≈ assessment of accuracy of computational model
Validation ≈ assessment of the degree to which a computational model is an accurate representation of physics being modelled

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)***





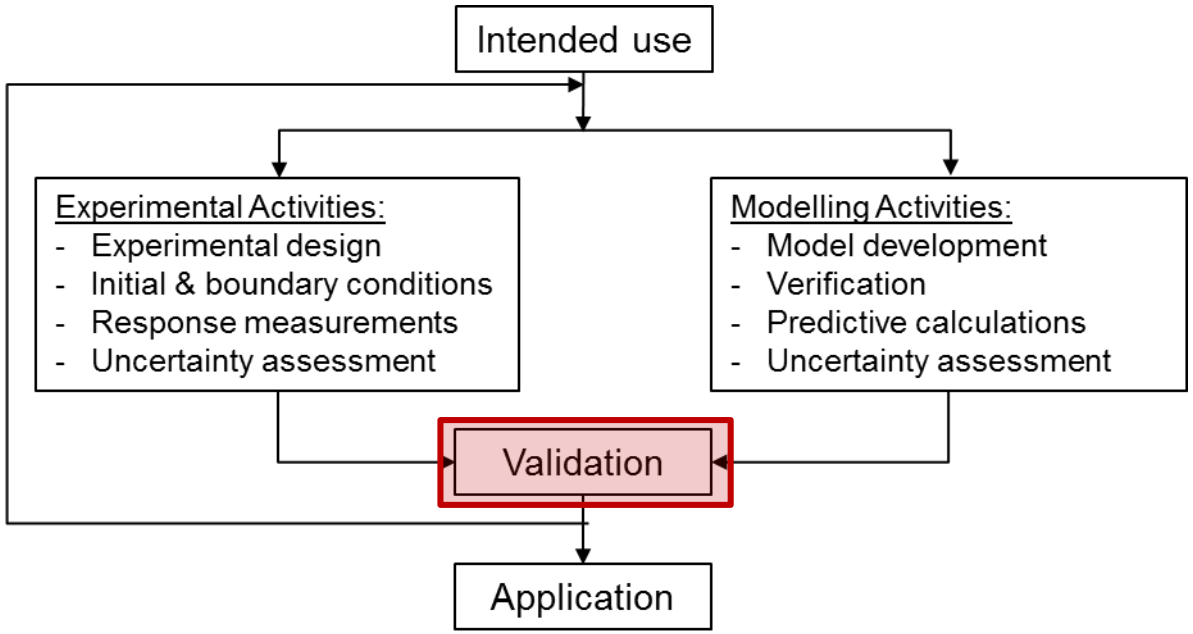
Conclusion: 4 people – 4 setups?

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)***



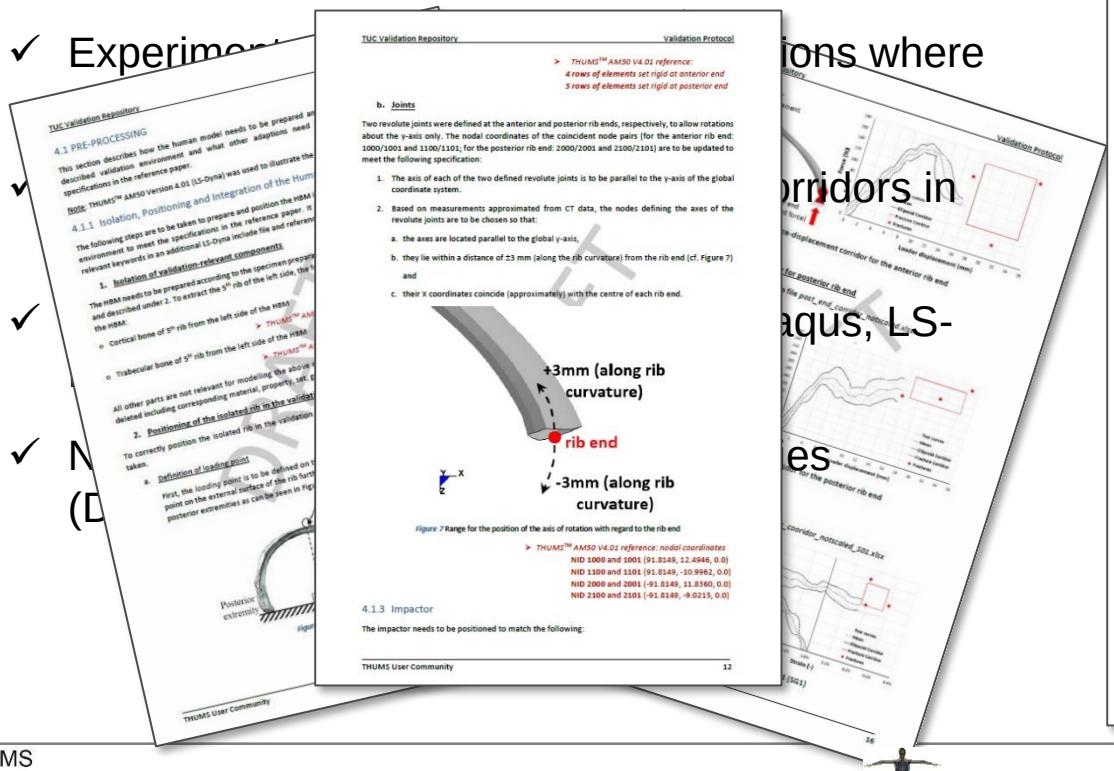
Challenges

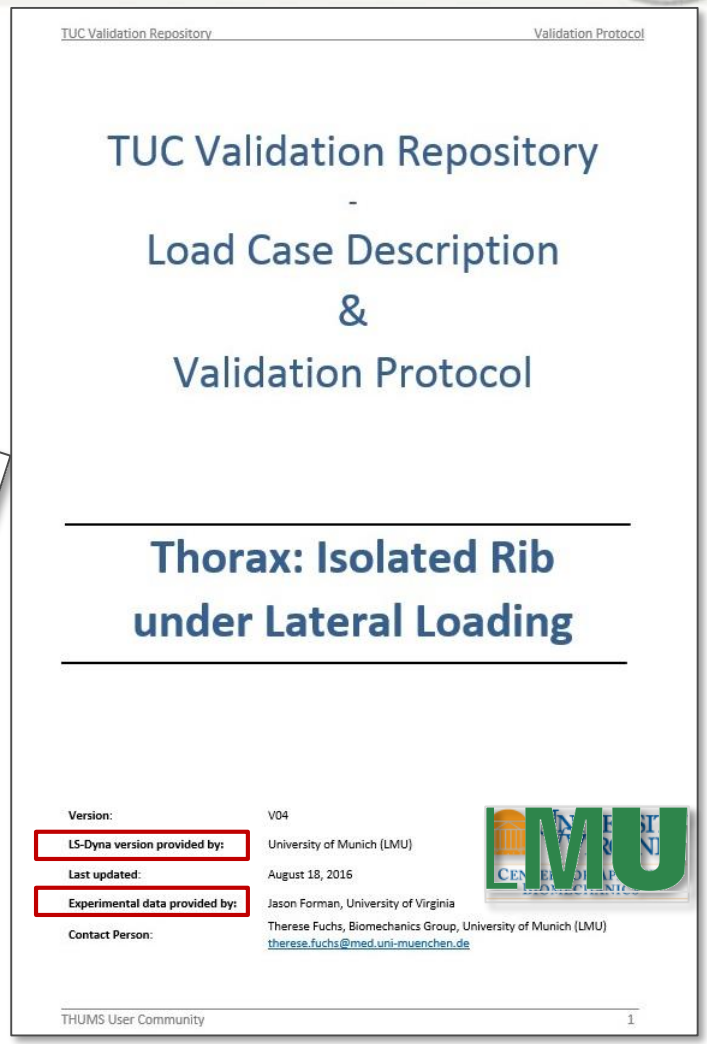
- Indirect validation
- Model development and verification
- Rating of validation results

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





TUC Validation Repository

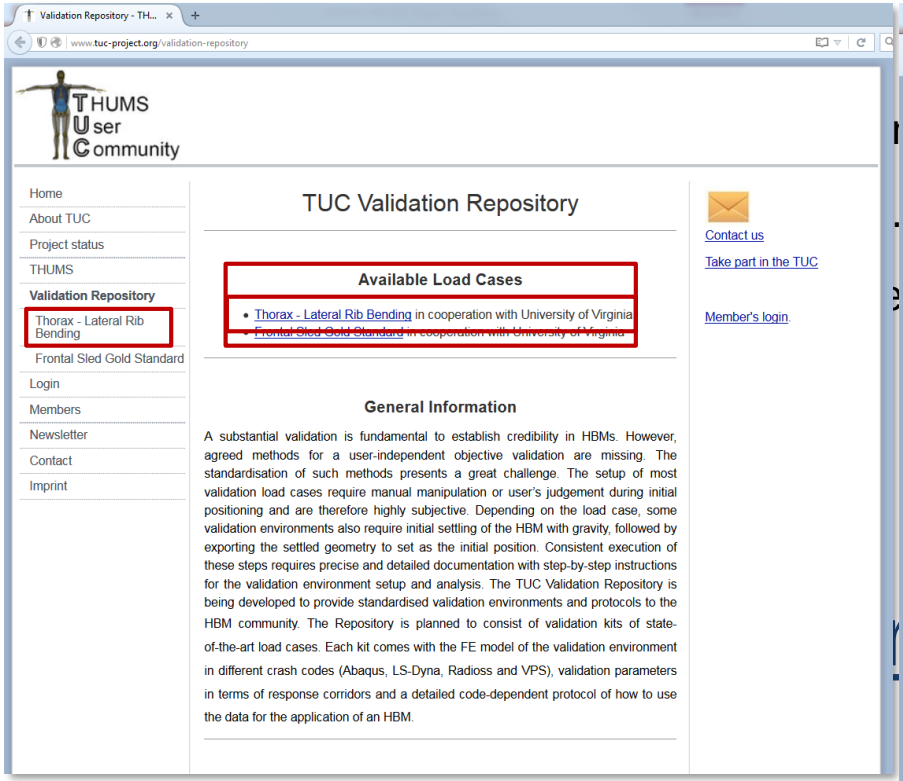
Benefits

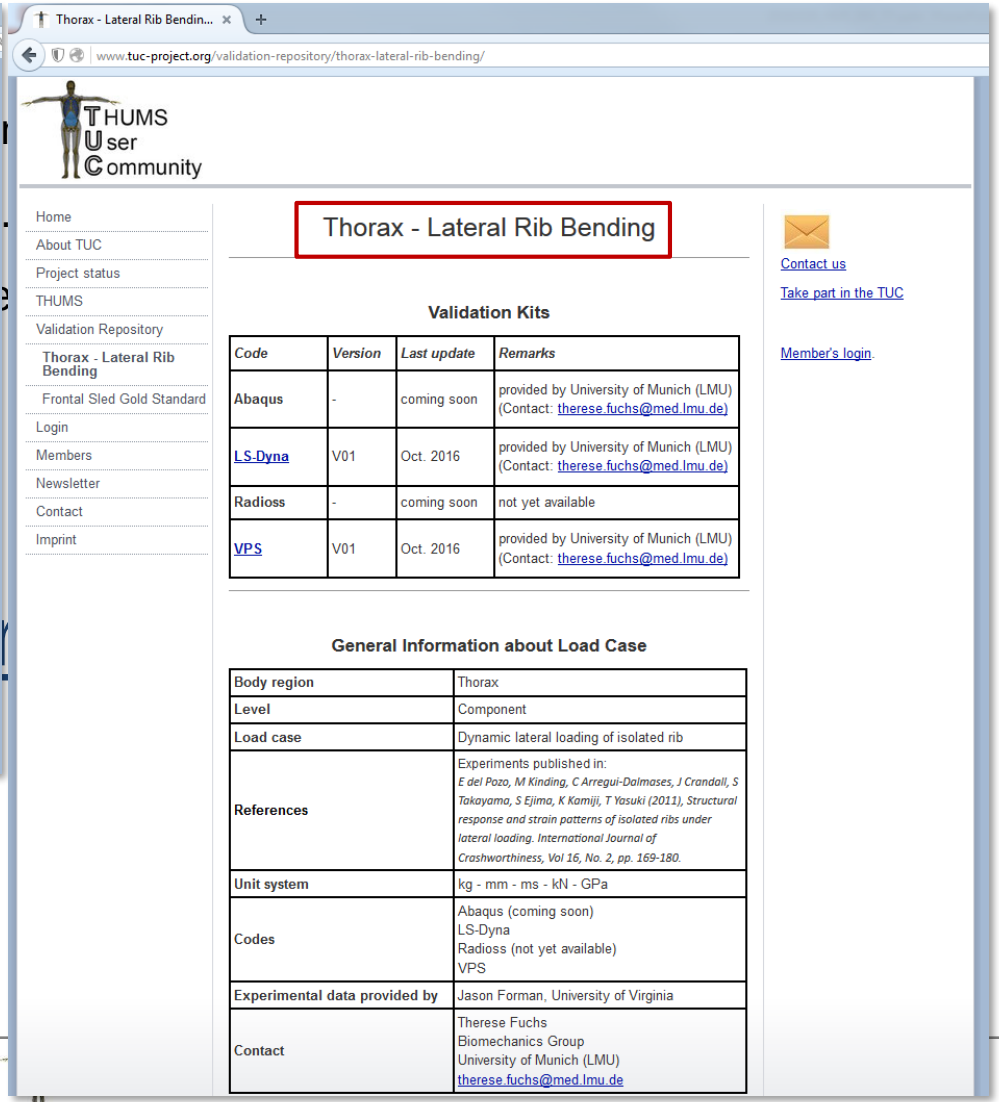
- ✓ User independence: Minimisation of manual manipulation or user's judgment during initial positioning/ settling with gravity
  - → Consistent execution requires a precise and detailed documentation with step-by-step instructions for the pre- and post-processing procedure
  - → Documentation so that 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





www.tuc-project.org/validation-repository

TUC Validation Repository

Outlook

→ Gold standard validation environment to be published in 2016

→ Experimental data provided by University of Virginia

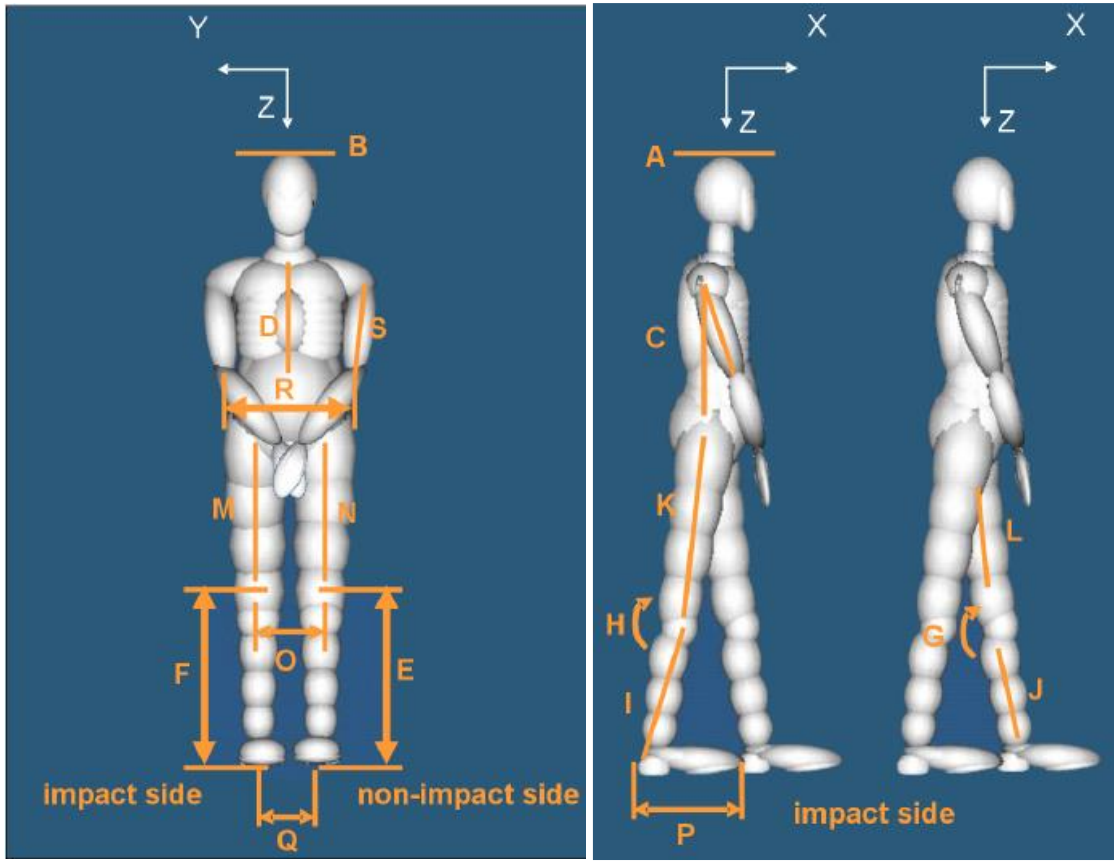
→ Further validation environments to be published within **follow-up project**

www.tuc-project.org/validation-repository

Agenda

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

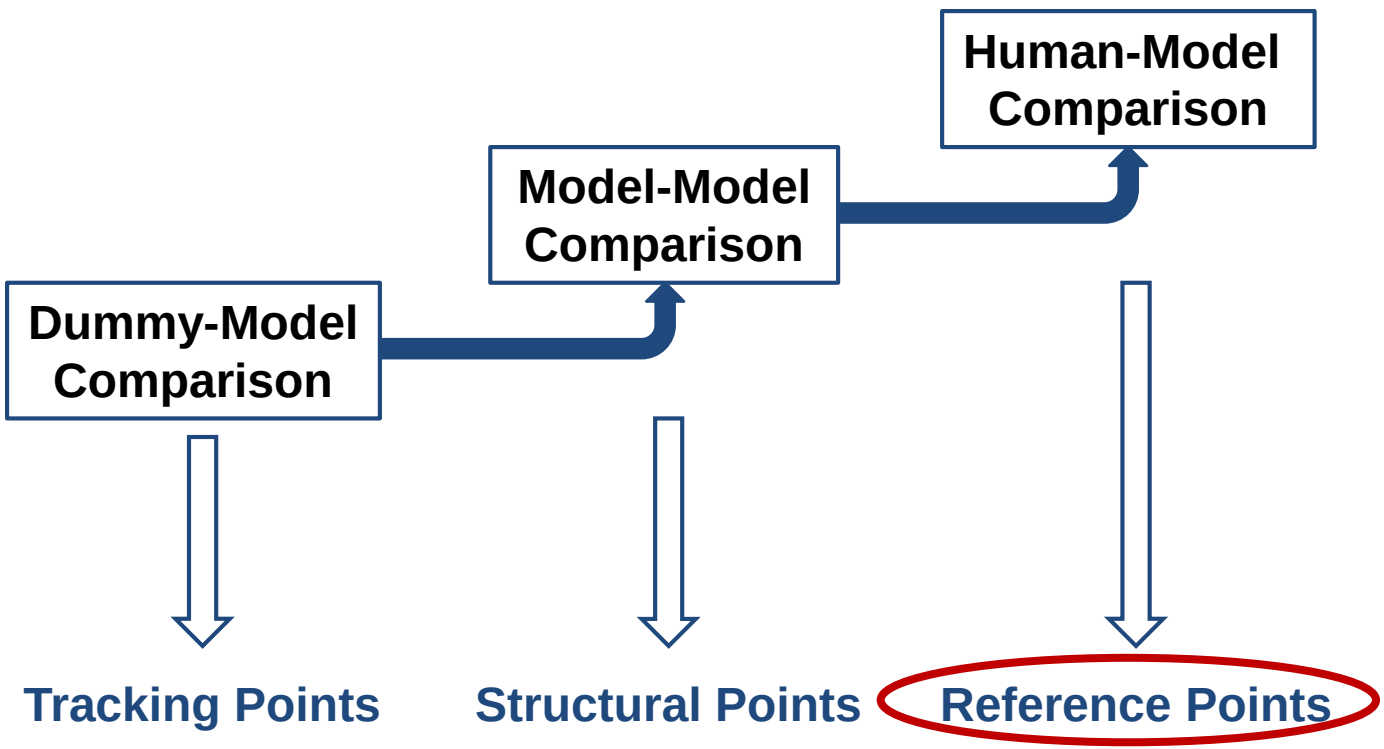
Why Reference Points?

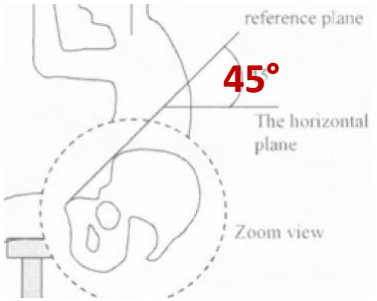


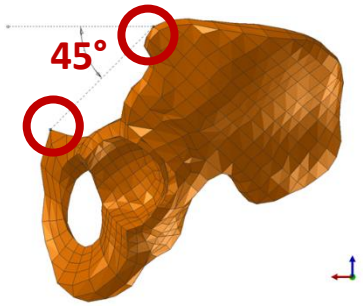
SAE J2782

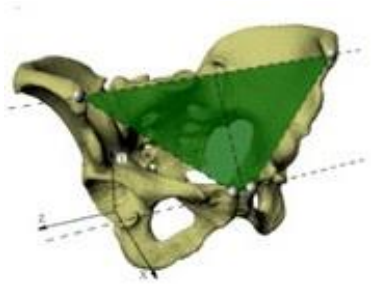
A: Angle of X axis of head accelerometer
B: Angle of Y axis of head accelerometer
C: Angle of thoracic spine about Y axis
D: Angle of thoracic spine about X axis
E: Vertical height from ground to non-impact knee joint center
F: Vertical height from ground to impact knee joint center
G: Angle between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









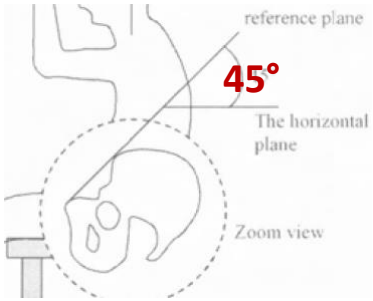
Why Reference Points?

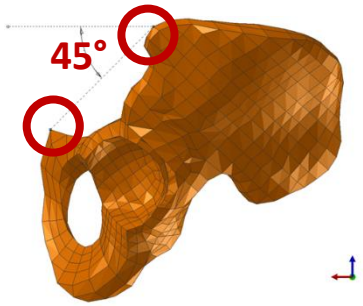
Definition of anatomically meaningful postures of pedestrians and occupants

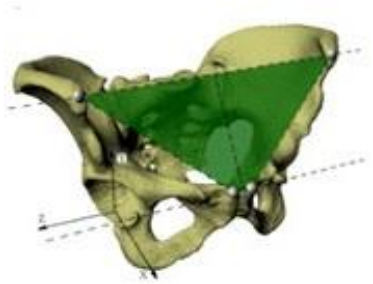
- Comparability between HBMs and real human beings
- Building a kinematic chain for positioning
- Identifiably on FE models and human beings (CT/MRI/palpable)
- Re-meshing resistant

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

- Long term – to be defined once for each HBM







Reference Points

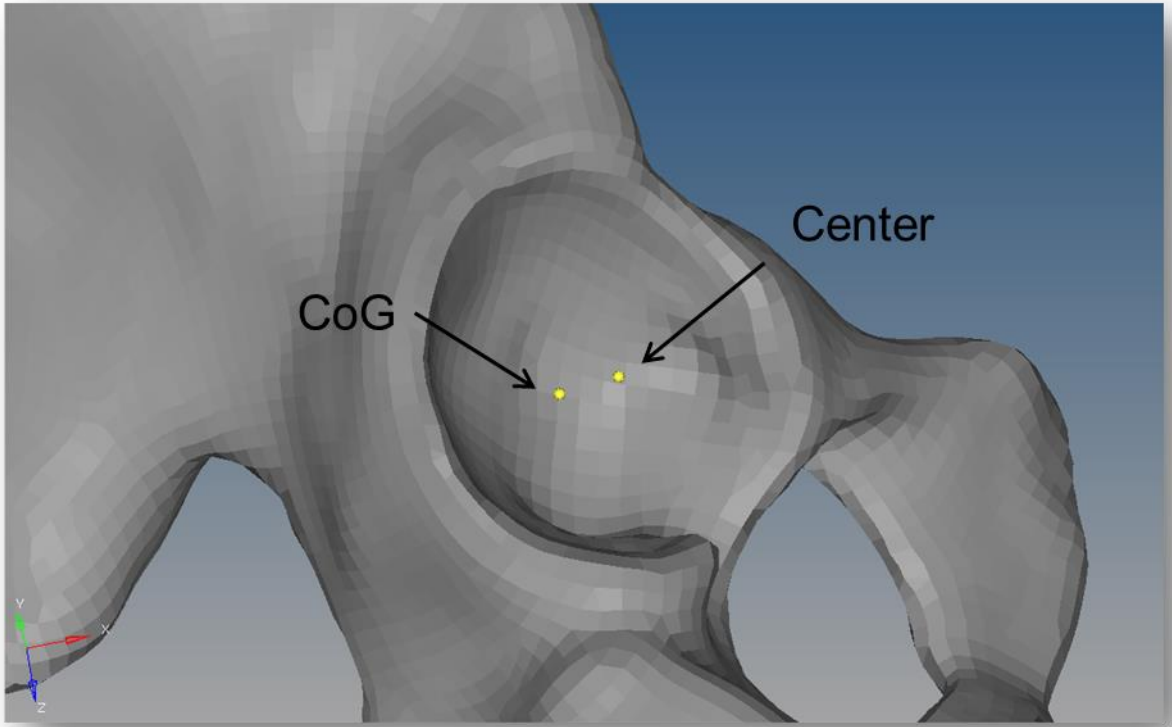
Center = the point equidistant from the points on the surface

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)

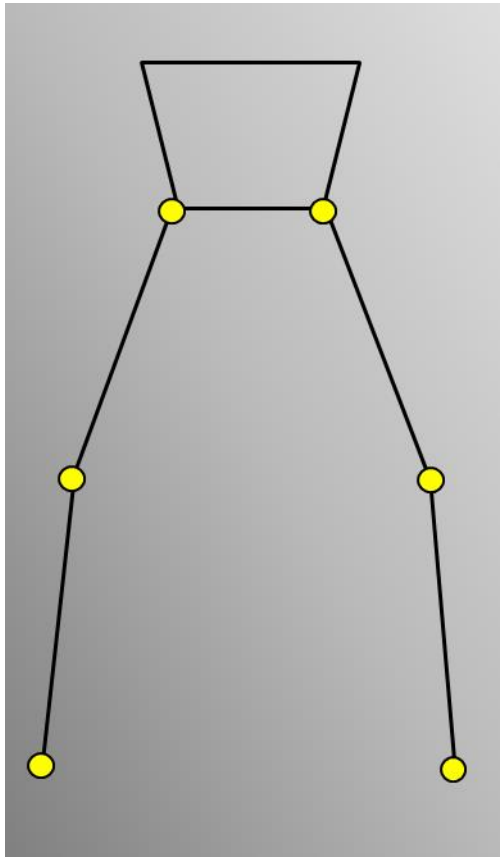


Reference Points

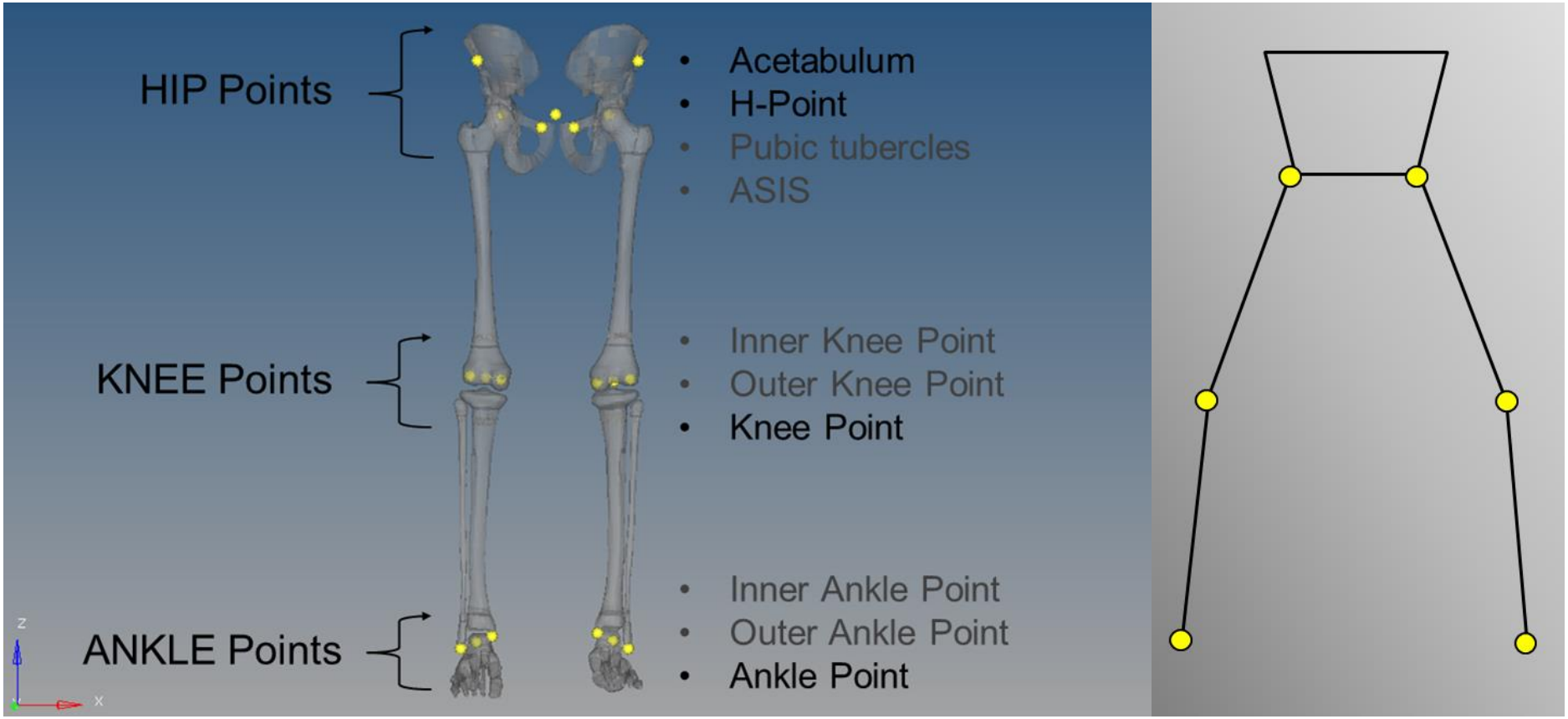
1. **Functional Reference Points**
   - Building a kinematic chain for pedestrian/occupant positioning
   - Defining angles and distances to non-ambiguously describe the position of the pedestrian/occupant in the global coordinate system

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

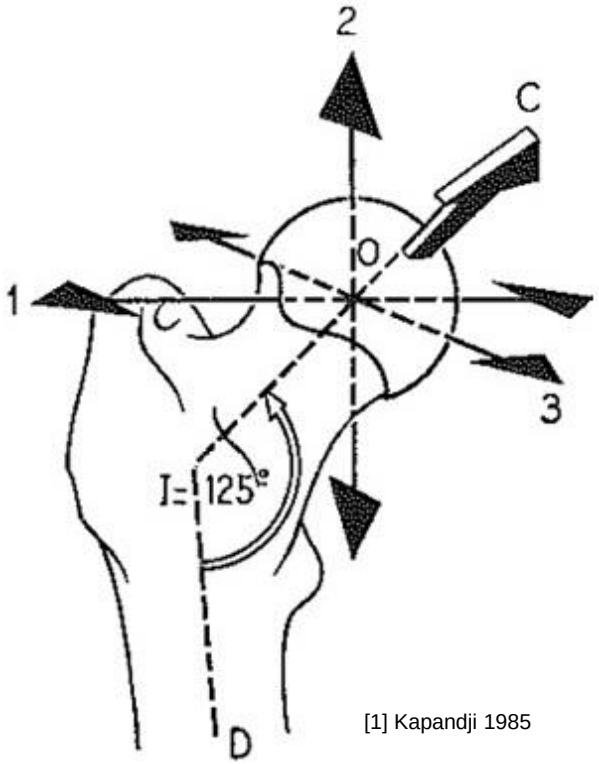


Reference Points: Example HIP

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

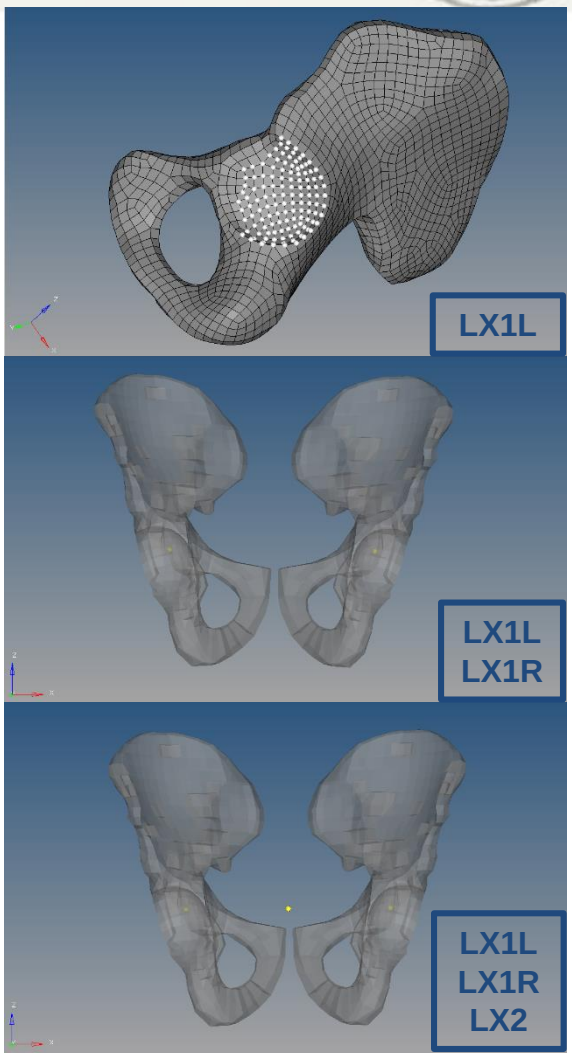
Reference Points: Example HIP

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**



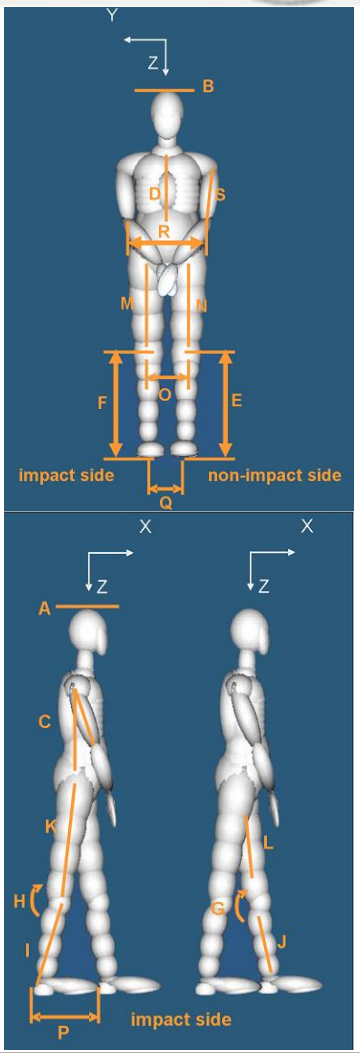
H-Point

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



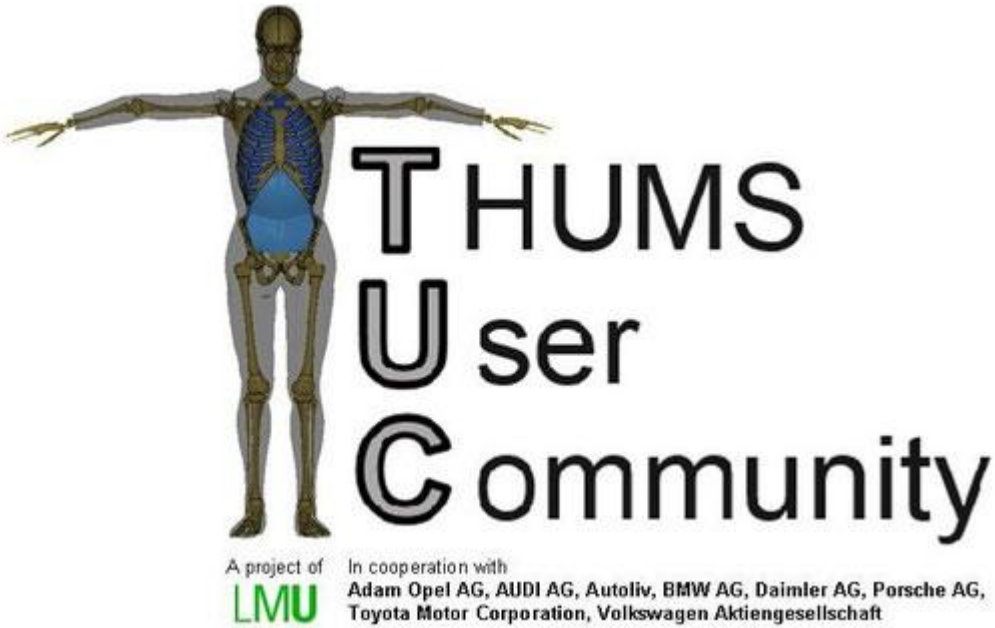
Reference Points: Limitations

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!