VIRTUAL TESTING
#1: HUMAN MODELING
IN PEDESTRIAN PROTECTION

Human Model Positioning using pre-Simulation

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carhs
Empowering Engineers

Human Model Positioning

Contents

- Challenges in HM positioning
- Positioning methods
- Kinematics Model
- Pre-Simulation model
- Position Quality measures

Human Model Positioning

Challenges in HM positioning

- Complex joint kinematics
- Column posture
- Ligaments and joint capsules
- Soft tissue positioning
- Inner organs shape and position

Challenge: Obtain a biomechanically „correct“ posture

Human Model Positioning

What is a biomechanically „correct“ posture?

- I do not know.

How do we get there?

- Pre-Simulation
- Mesh Morphing
- Geometry morphing
- AI approaches?
- …

Human Model Positioning

Pre-Simulation

Idea: trust in model definitions and validation

- „correct“ position is based on simulation model properties (Ligaments, capsules, tissue properties,…)
- advantage: it is not necessary to know the „correct“ posture exactly in advance
- disadvantage: mesh quality issues may occur

Human Model Positioning

Mesh Morphing

„correct“ position is knowledge based, has to be known for any posture in advance

- advantage: mesh quality is always good
- disadvantage: exhaustive posture knowledge base is needed

Geometry (mesh independent) Morphing

completely parametrized geometry model necessary

- Exhaustive posture knowledge base necessary
- most „elegant“ approach to obtain any posture

Human Model Positioning

- Steps of Pre-Simulation positioning

1. Kinematics model for Pre-Positioning

2. Simulation model for Presimulation

Human Model Positioning

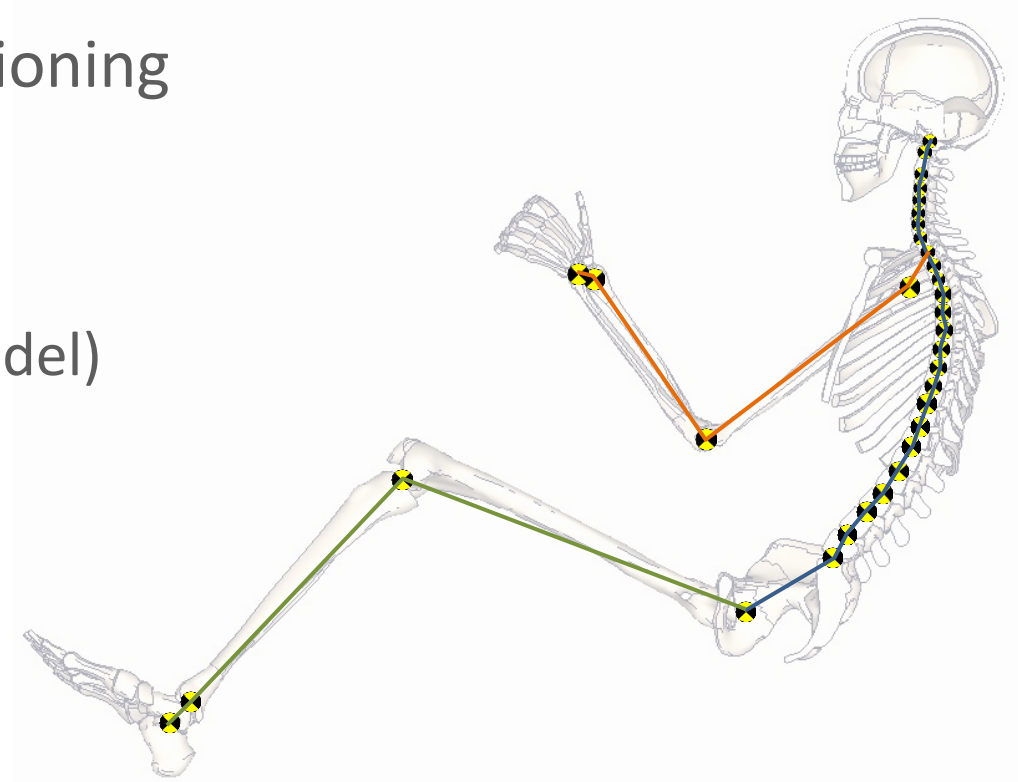
- Steps of Pre-Simulation positioning

1. Kinematics model for Pre-Processor Positioning

Requirements

- Realistic motion description of the human (model)
- Description by the means of kinematic joints

➢ Conflicting requirements?

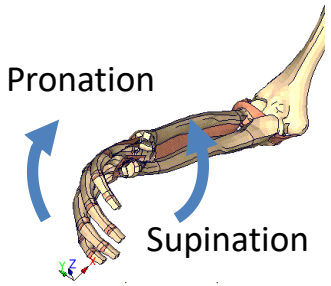


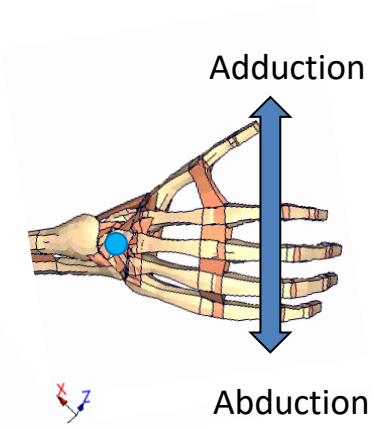
Human Model Positioning

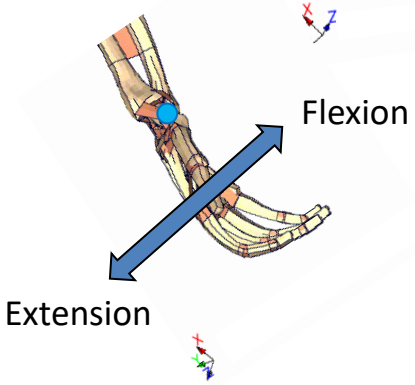
- Steps of Pre-Simulation positioning

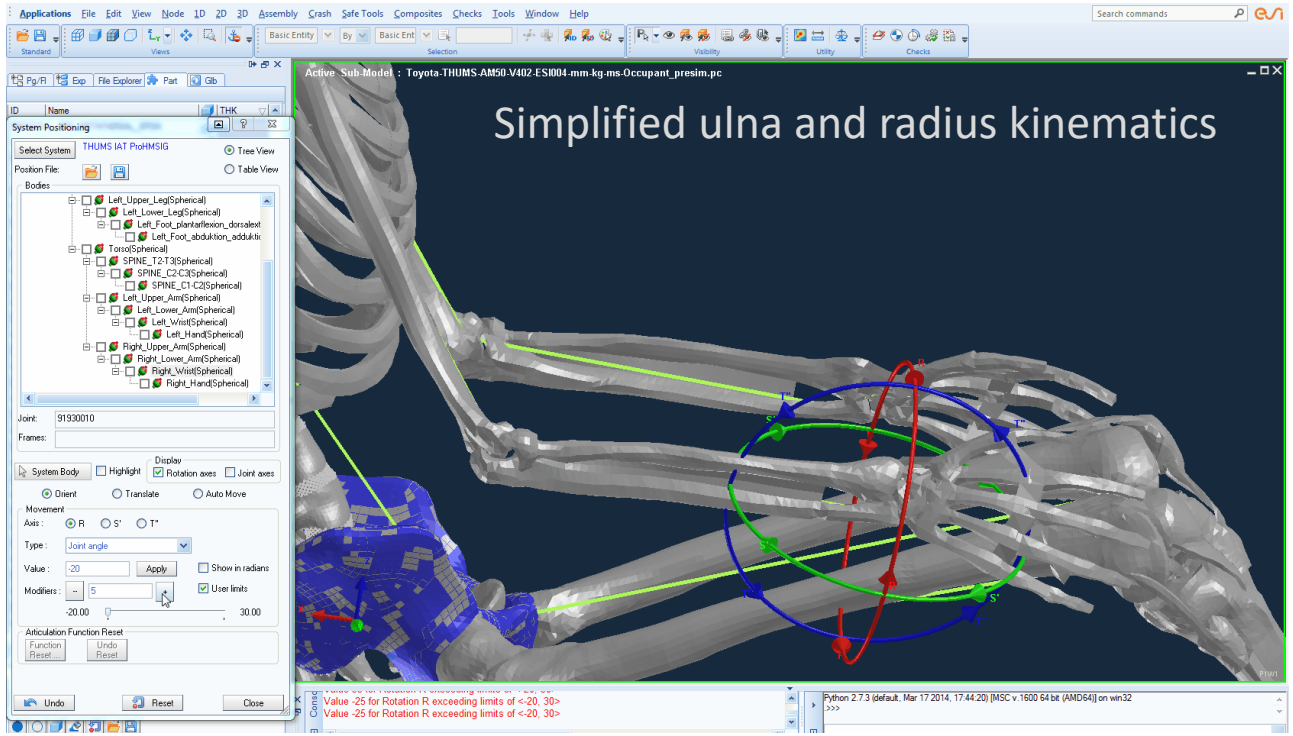
1. Kinematics model for Pre-Processor Positioning

Example: lower Arms







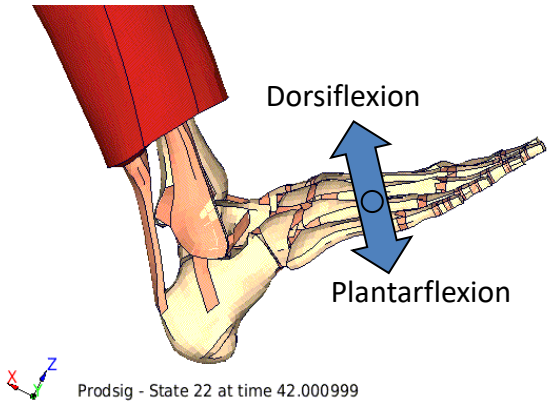


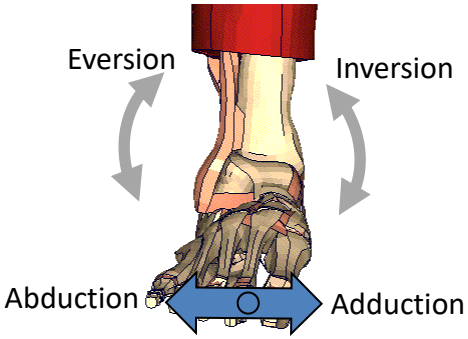
Human Model Positioning

- Steps of Pre-Simulation positioning

1. Kinematics model for Pre-Processor Positioning

Example: Ankle Joint

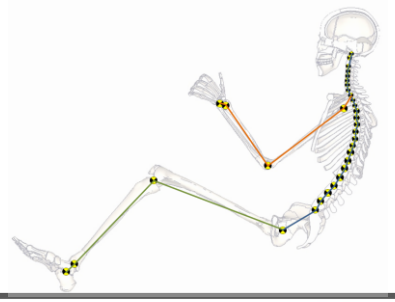




mere plantarflexion and dorsiflexion are adjusted in the ankle joint proper (talocrural joint).

All other adjustments are a combination of ankle joint proper and subtalar joint (talocalcaneal joint)

Supination: Inversion+Plantarflexion+Adduction
Pronation: Eversion+Dorsalextension+Abduction



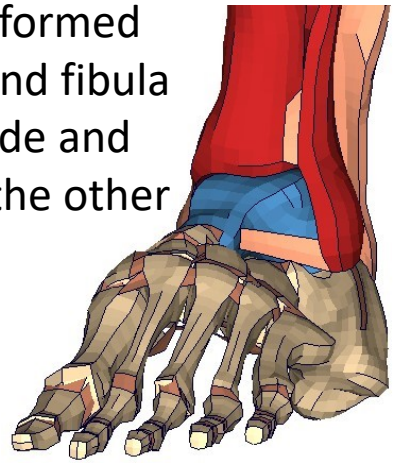
Human Model Positioning

- Steps of Pre-Simulation positioning

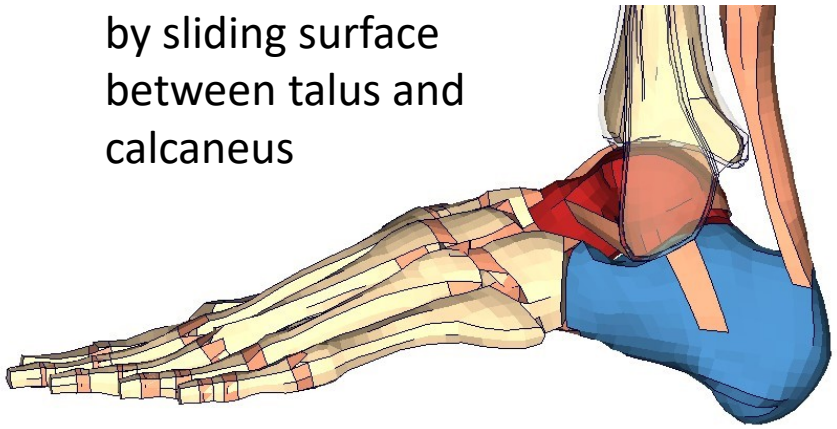
1. Kinematics model for Pre-Processor Positioning

Example: Ankle Joint in Simulation model

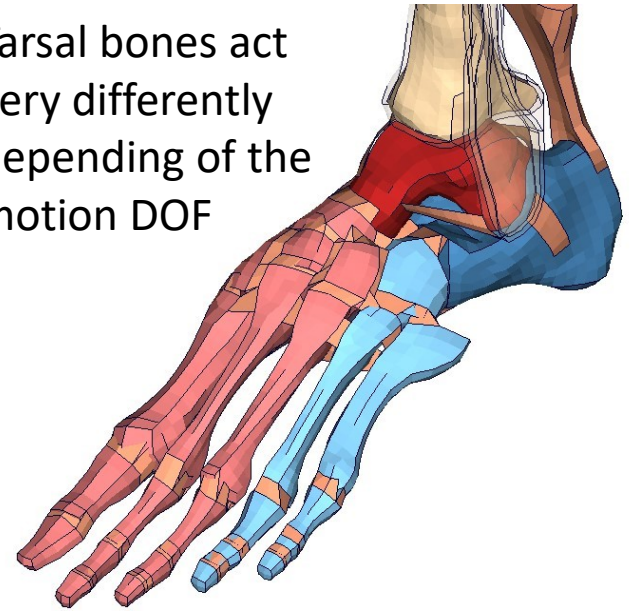
Ankle joint: "saddle" formed by tibia and fibula on one side and talus on the other side



Subtalar joint: formed by sliding surface between talus and calcaneus



Tarsal bones act very differently depending of the motion DOF

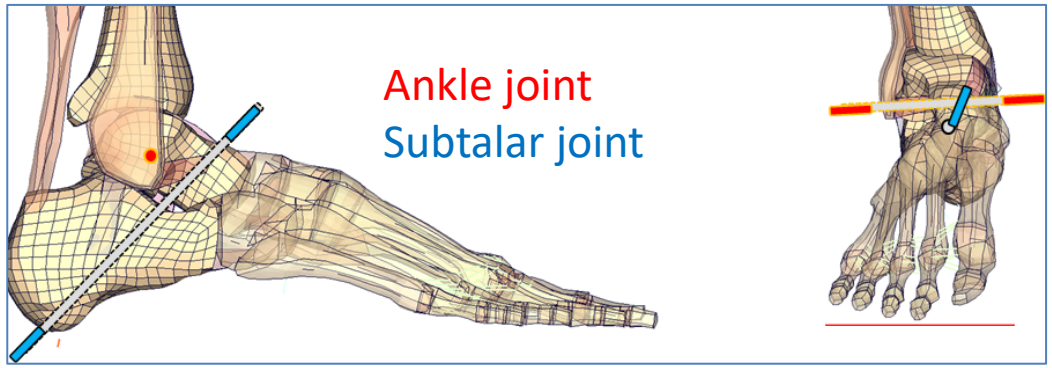


Human Model Positioning

- Steps of Pre-Simulation positioning

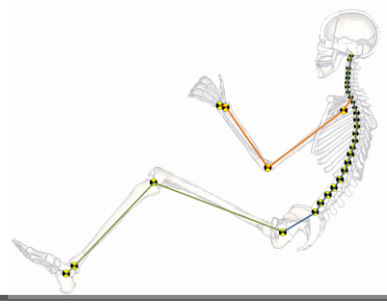
1. Kinematics model for Pre-Processor Positioning

Example: Ankle Joint in Kinematics model



Adjustments in the kinematic model are simplified by two joints as sketched

In simulation position is determined by contacts, ligaments- and tissue properties

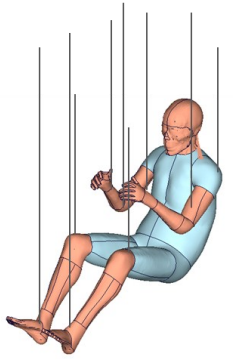


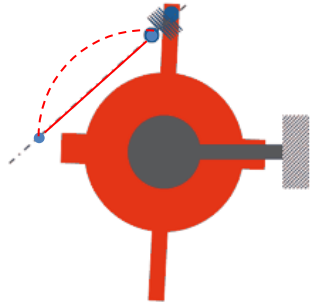
Human Model Positioning

- Steps of Pre-Simulation positioning

2. Presimulation ->

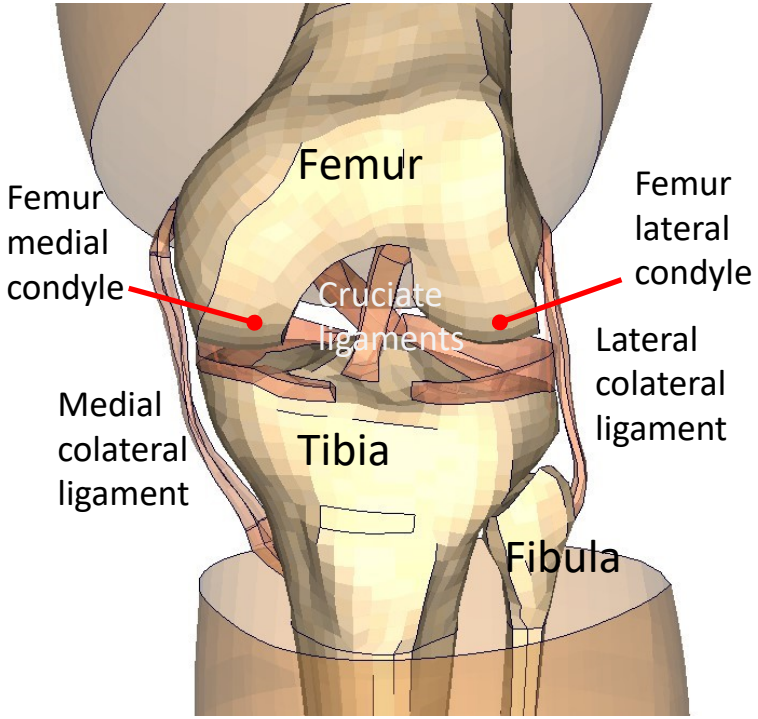
  - Guided motions lead to well predictable simulation time and model loads
  - Target positions are reached almost precisely.
  - Unreachable or unprecise positions from pre-processing are compensated by spring stiffnesses of guided nodes attachment. Stiffnesses lead to a positioning equilibrium and prevent the model from being destroyed.

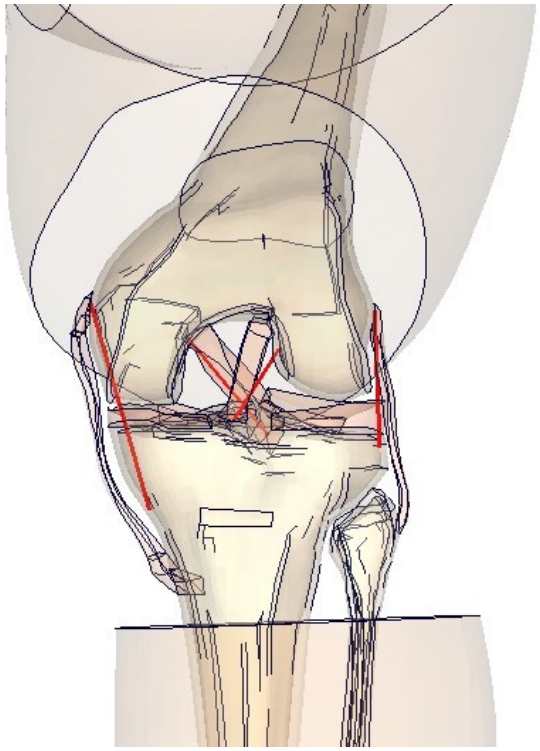


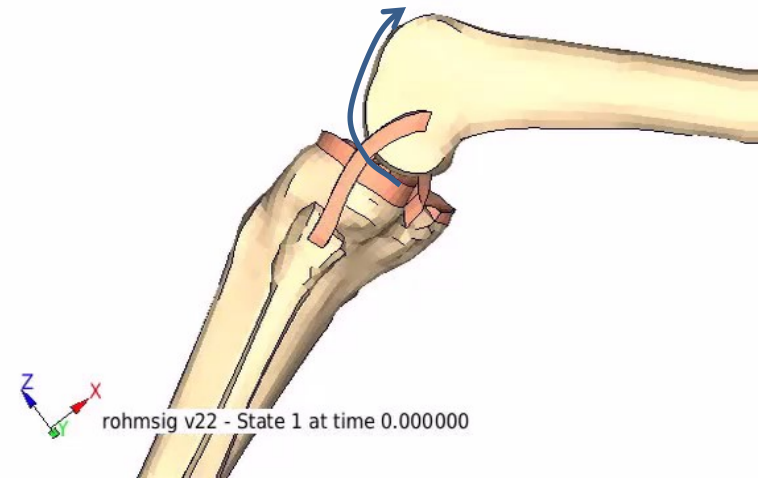


Human Model Positioning

- Individual solution for correct positioning of each articulation
- Example: knee
- -> complex motion guided by ligaments and sliding of Tibia plateau on Femur Condyles

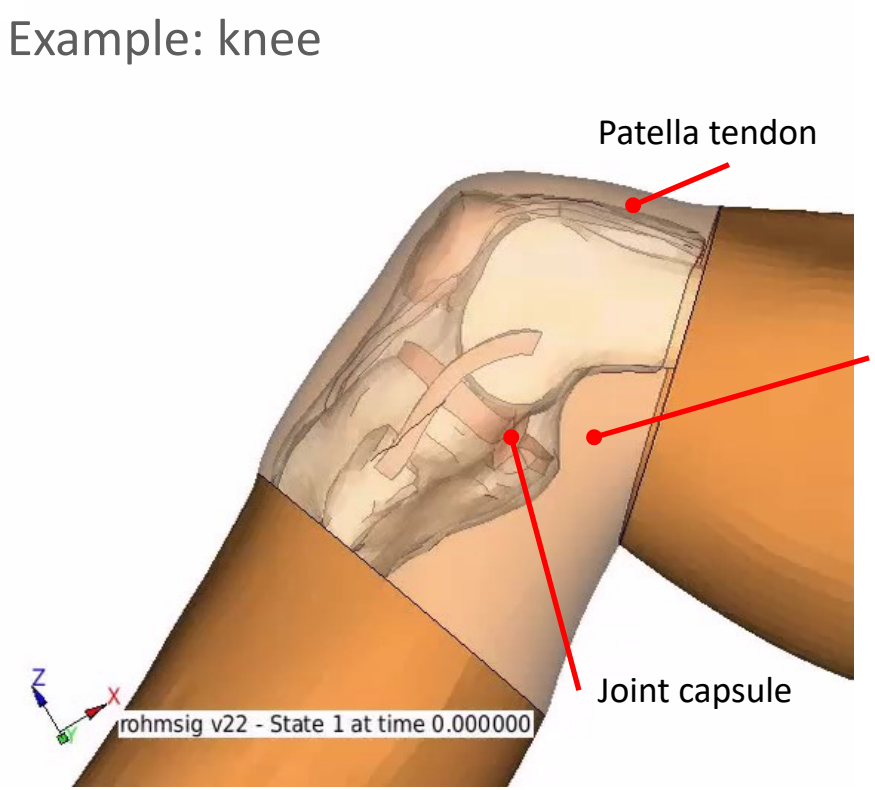




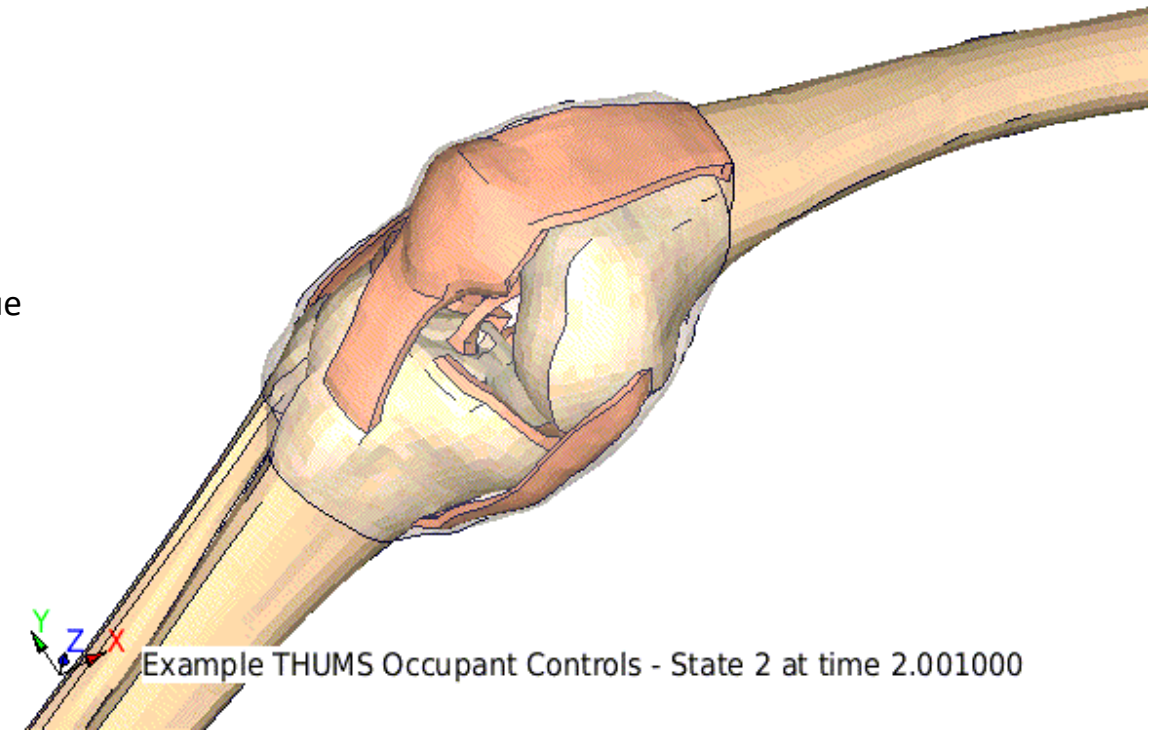


Human Model Positioning

- Individual solution for correct positioning of each articulation
- Example: knee



Pre-Simulation model



Model without measures

Human Model Positioning

- Individual solution for correct positioning of each articulation
- Example: spinal column
- Challenges
- „correct“ individual spinal curveature
- vertebrae positions and angles, shape and position of intervertebral discs
- Ligaments, abdomen cavity and intestines positioning

Human Model Positioning

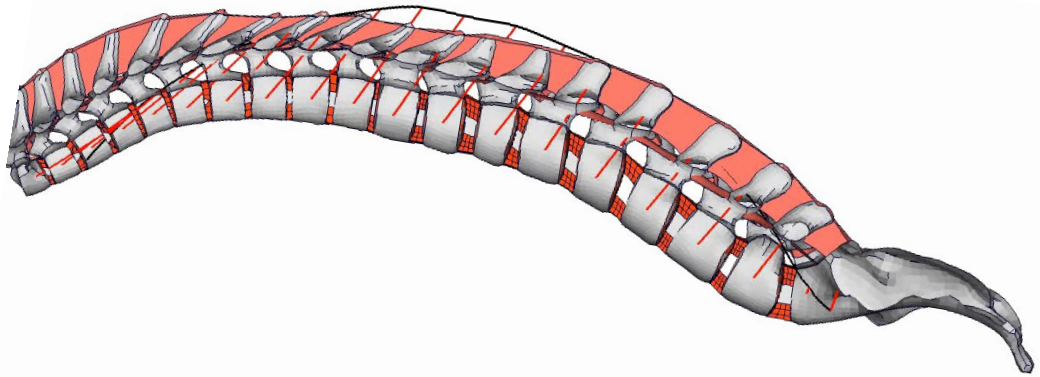
- Individual solution for correct positioning of each articulation
- Example: spinal column
- position measurement and application (individual, statistical)

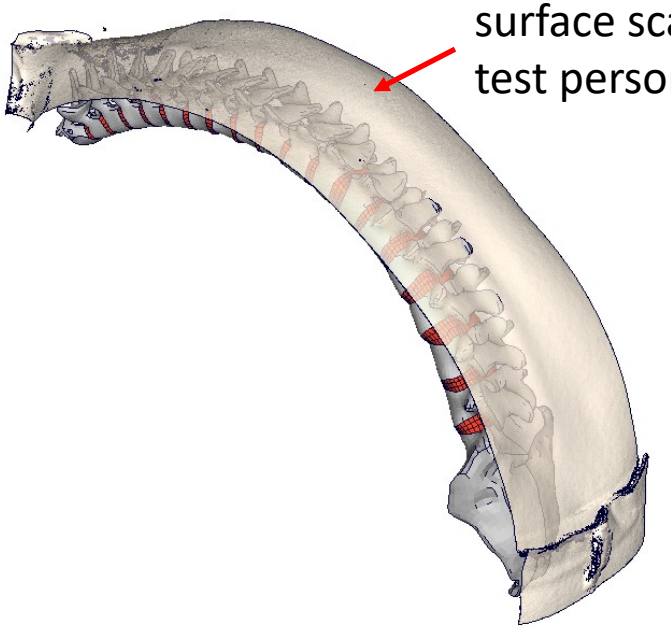
Messung_ID	5025	5026	5027
Messung	1	2	3
T1_2	7	7	7
T2_3	7	8	8
T3_4	7	6	8
T4_5	10	11	9
T5_6	5	5	7
T6_7	4	3	-2
T7_8	-2	-1	2
T8_9	5	5	9
T9_10	6	5	-1
T10_11	-3	-2	0
T11_12	4	4	5
T12_L1	4	4	8
L1_2	9	9	9
L2_3	8	8	4
L3_4	3	3	9
L4_5	7	8	-9
L5_S1	3	1	-20
Wirbelsaeulenlaenge	508.0	510.0	542.0
Regionalwinkel_BWS	50.0	51.0	52.0
Regionalwinkel_LWS	34.0	33.0	2.0
SAK_HG	62.0	63.0	92.0
Neigung	98.0	98.0	97.0

Source: Spinal Curvature Measurements to Position Human Body Models in Occupant Safety Applications.
Daniel Hintze, Kai Ikels, Özgür Cebeci, 8th International Symposium: Human Modeling and Simulation in Automotive Engineering, November 19 - 20, 2020

Human Model Positioning

- Individual solution for correct positioning of each articulation
- Example: spinal column
- position application: forward flexion: positioning on spline gathered from measurement





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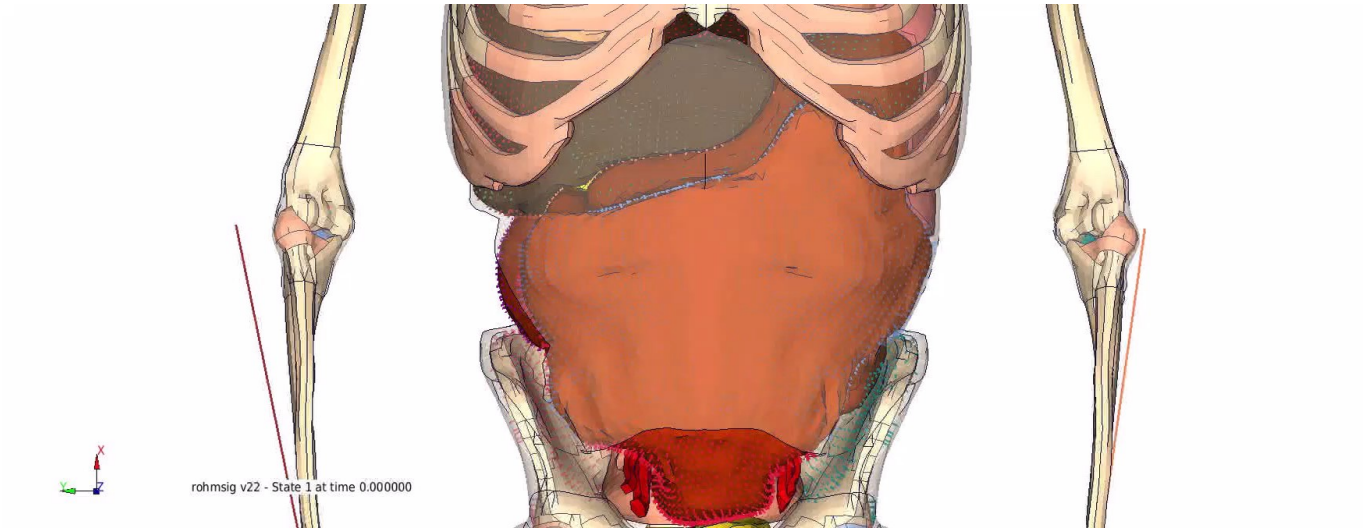
Human Model Positioning

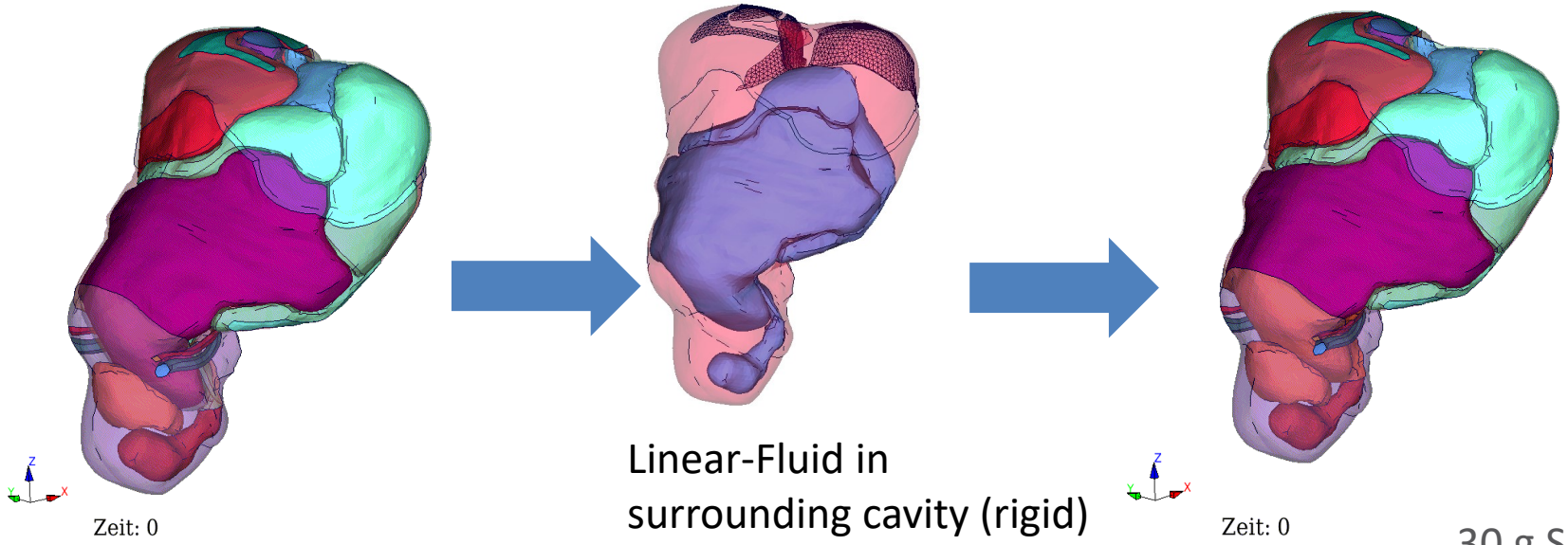
- Individual solution for correct positioning of each articulation
- Example: spinal column
- Thorax/abdomen cavity and internal organs
- Challenge: Shape, position and volume of internal organs



Simple solution:
Intestines are tied together and to the abdominal wall.
Position shape and volume determined by model properties

Human Model Positioning

- Individual solution for correct positioning of each articulation
- Example: spinal column
- Thorax/abdomen cavity and internal organs
- Challenge: Shape, position and volume of internal organs

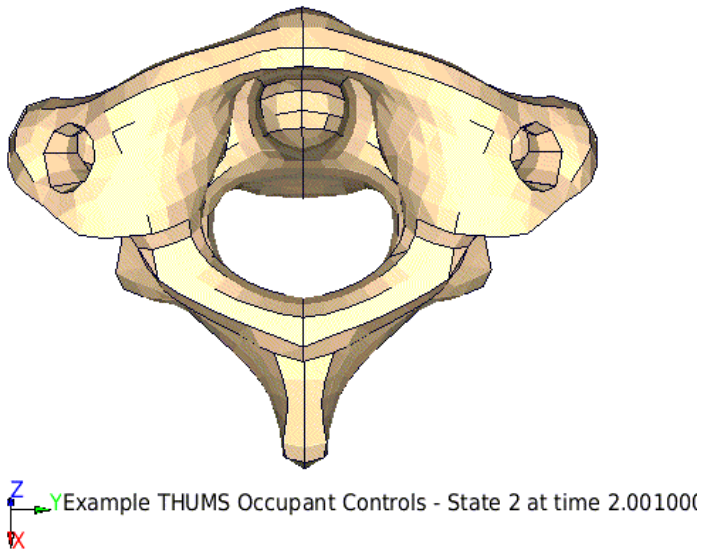


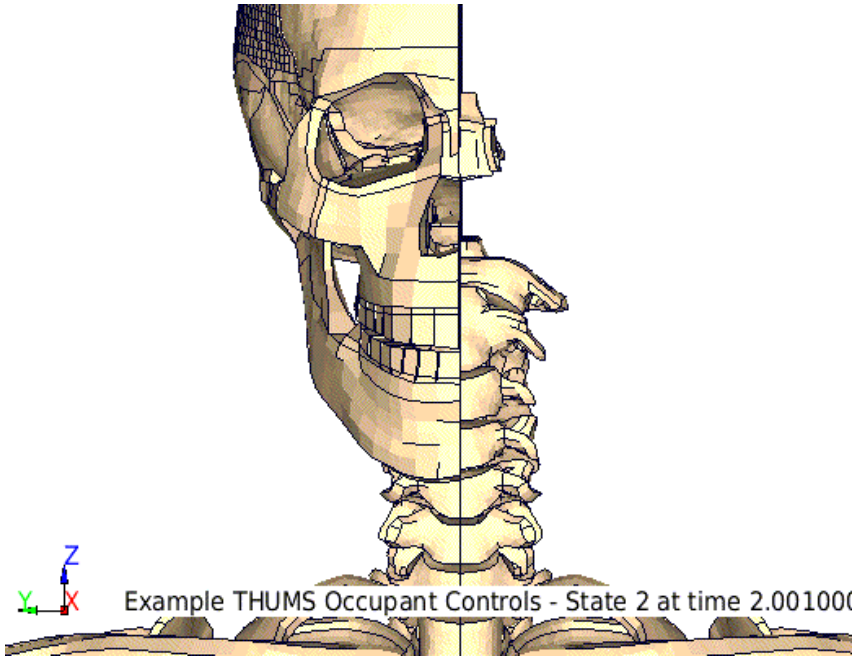
Advanced solution:
Internal organs are embedded in a linear fluid in the (closed) abdomen cavity. Position and volume of each organ is determined by pressure equilibrium. No additional voids appear

30 g Simulation

Human Model Positioning

- Individual solution for correct positioning of each articulation
- Example: spinal column
- Vertical rotation: limited model capabilities for head and thorax rotations



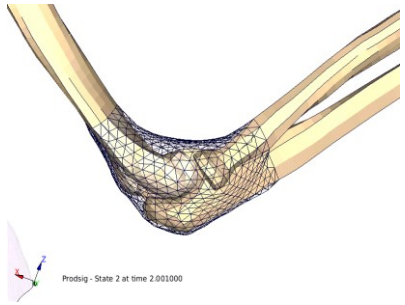


Human Model Positioning

A few positioning quality criteria

- Joints: Distance, Intersections

- Capsules: avoid cavities, wrinkling



- Ligaments: avoid wrinkling

- Soft tissue: smooth surface, element quality, no Volume change,...
- Abdomen cavity, internal organs : no voids, no volume change of tissues,..

Human Model Positioning

- Outlook
- internal organs
- Hands
- Column vertical rotation
- large positioning ranges

THANK YOU FOR YOUR ATTENTION