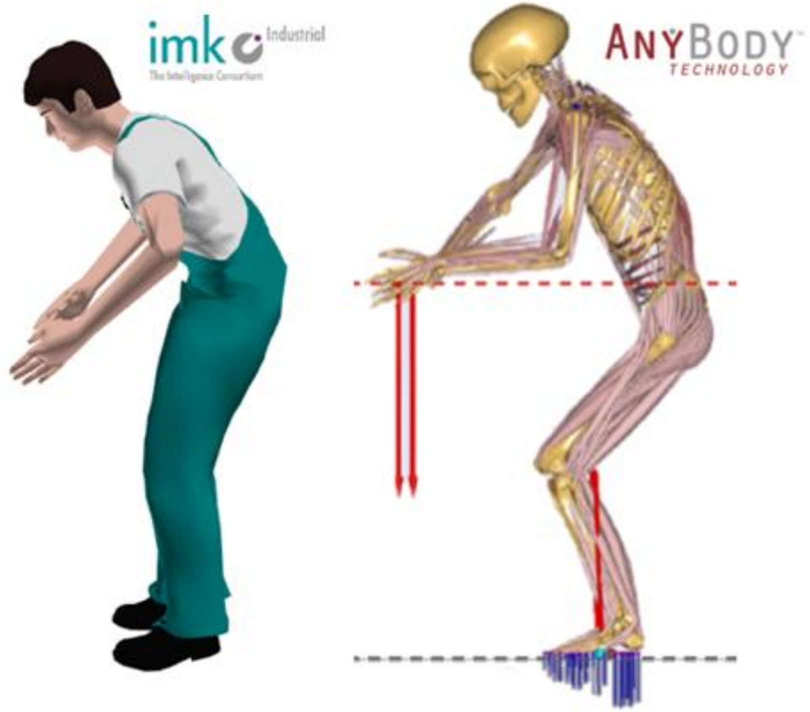
Oct 22, 2024

DigitalExonomics | Musculoskeletal Exoskeleton Assessment with AnyBody™



The webcast will begin shortly...

Outline

- Introduction to the AnyBody Modeling System
- Presentation
- Upcoming AnyBody events
- Question and answer session

Presenters

- Dr. **Sascha Ullmann**

Head of Digital Planning Ergonomics

Imk Industrial Intelligence GmbH, Chemnitz

- M.Sc. **Lukas Gschoßmann**

Research Associate Biomechanics

Laboratory for Biomechanics OTH Regensburg

Host

Kristoffer Iversen

Technical Sales Executive

AnyBody Technology

Control Panel

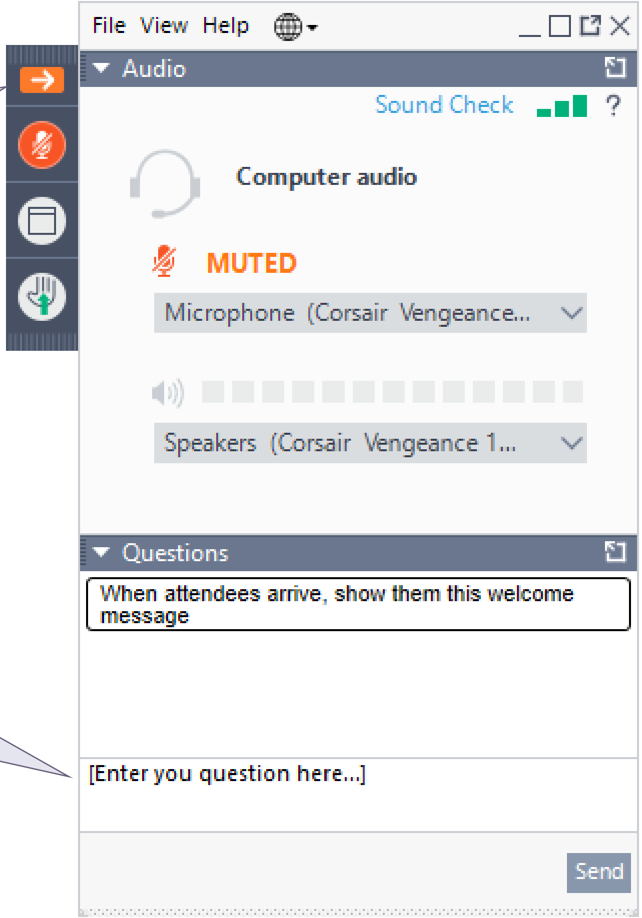
The Control Panel appears on the right side of your screen.

Submit questions and comments via the Questions panel.

> *Questions will be addressed at the end of the presentation. If your question is not addressed, we will do so by email.*

Expand/Collapse the Control Panel

Ask a question during the presentation



Musculoskeletal simulations

INPUT • Motion data

- Motion
- Forces

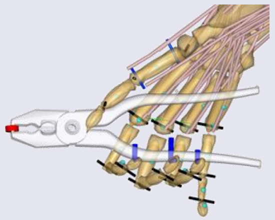
AnyBody Modeling System

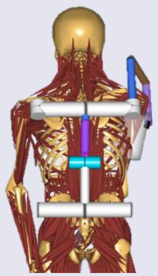
OUTPUT • Internal Body Loads

- Joint reaction forces
- Muscle forces
- Muscle activity
- Metabolic energy

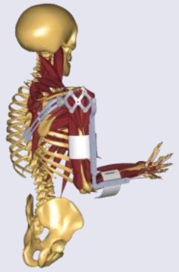
Motion analysis

Product design and optimization

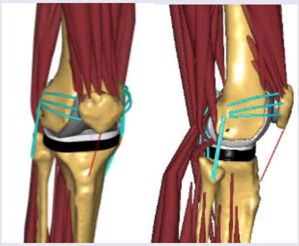




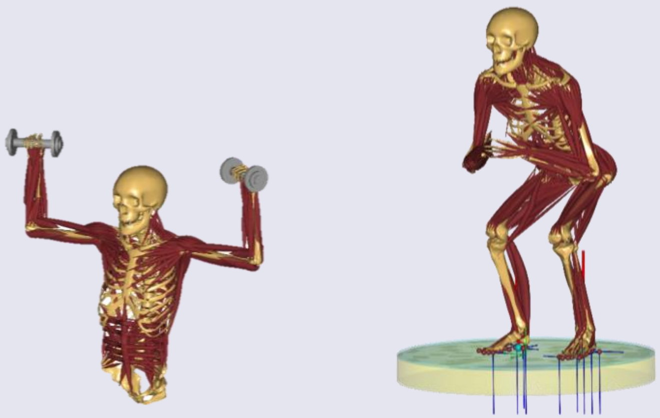
Ergonomics with/without exoskeletons



ANYBODY MODELING SYSTEM



Orthopedics and Rehabilitation



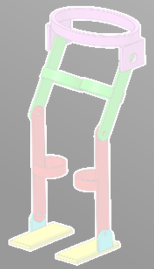
Sports

Automotive

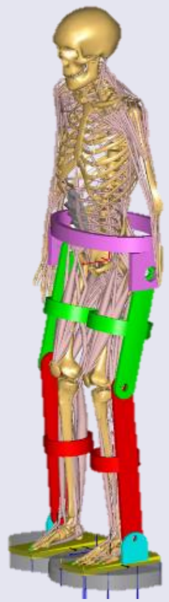
Workflow

Motions and forces

Body model

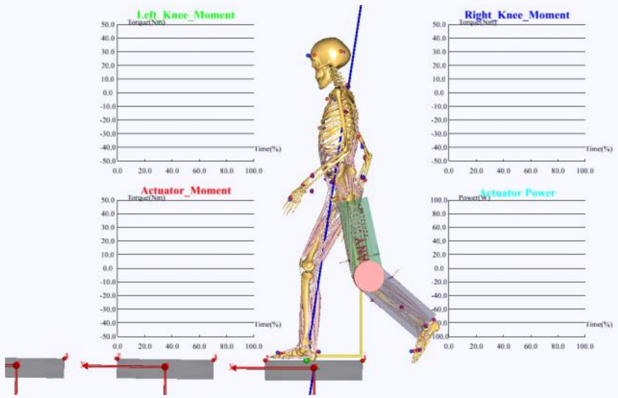


Environment model



Simulation

Inverse dynamics
Muscle recruitment



Internal body loads:
- Muscle forces
- Joint forces

Design Optimization

Post Processing
(e.g. Finite Element tools)

Digital Exonomics & ema 2 AnyBody

Digital Exonomics Overview

DIGITAL EXONOMICS

- **Topic:**
  Digital Work Design and Ergonomics Asessment for the Use of Occupational Exoskeletons
- **Term:** 10.09.2021 – 29.02.2024
- **Research Focus:**
  - Early efficiency analyses of exoskeletons using validated 3D simulations and markerless motion capture
  - Creation and enhancement of **interfaces** between a system for markerless motion capture (**Captury**), a biomechanical human model (**AnyBody**) and an ergonomic human model (**ema**) for detailed analyses and evaluations

Project Partners

imk industrial competence
the captury
Fraunhofer IPA
OTH Ostbayerische Technische Hochschule Regensburg

Associated Partners

Daimler Truck
Universitätsklinikum Tübingen – Institut für Arbeitsmedizin, Sozialmedizin und Versorgungsforschung
Mercedes-Benz
DB
AnyBody Technology
ottobock.
Hunic
Asklepios Klinikum Bad Abbach

Gefördert vom Bundesministerium für Bildung und Forschung

DLR Projektträger

imk Industrial Intelligence GmbH

imk Industrial
The Intelligence Consortium

2002
founded

Software & Consulting

> 500 clients
> 2000 projects
> 20 countries

imk automotive, Inc.
Columbia, SC, USA

TÜVRheinland ZERTIFIZIERT
Management System
ISO 9001:2015
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employees

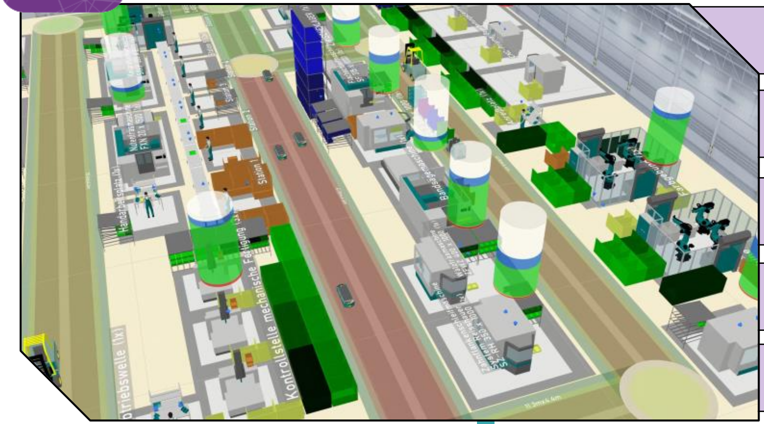
kununu TOP COMPANY
VON MITARBEITERN EMPFOHLEN!

imk Headquarter in Chemnitz, Germany

imk

From Factory to Workplace Design within one Software Suite

Plant Designer

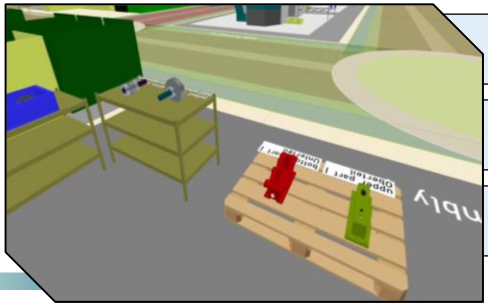


- Space requirement
- Resources
- Production costs
- Value Stream
- Material flow

Work Designer

- Layout
- Simulation
- Production time
- Ergonomics
- Walk paths

Virtual Reality

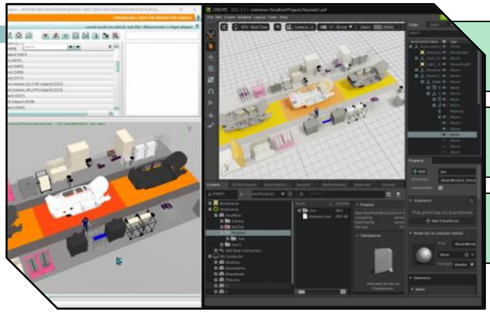


- Viewer
- Layout
- Try-Out

Human Robot Collaboration

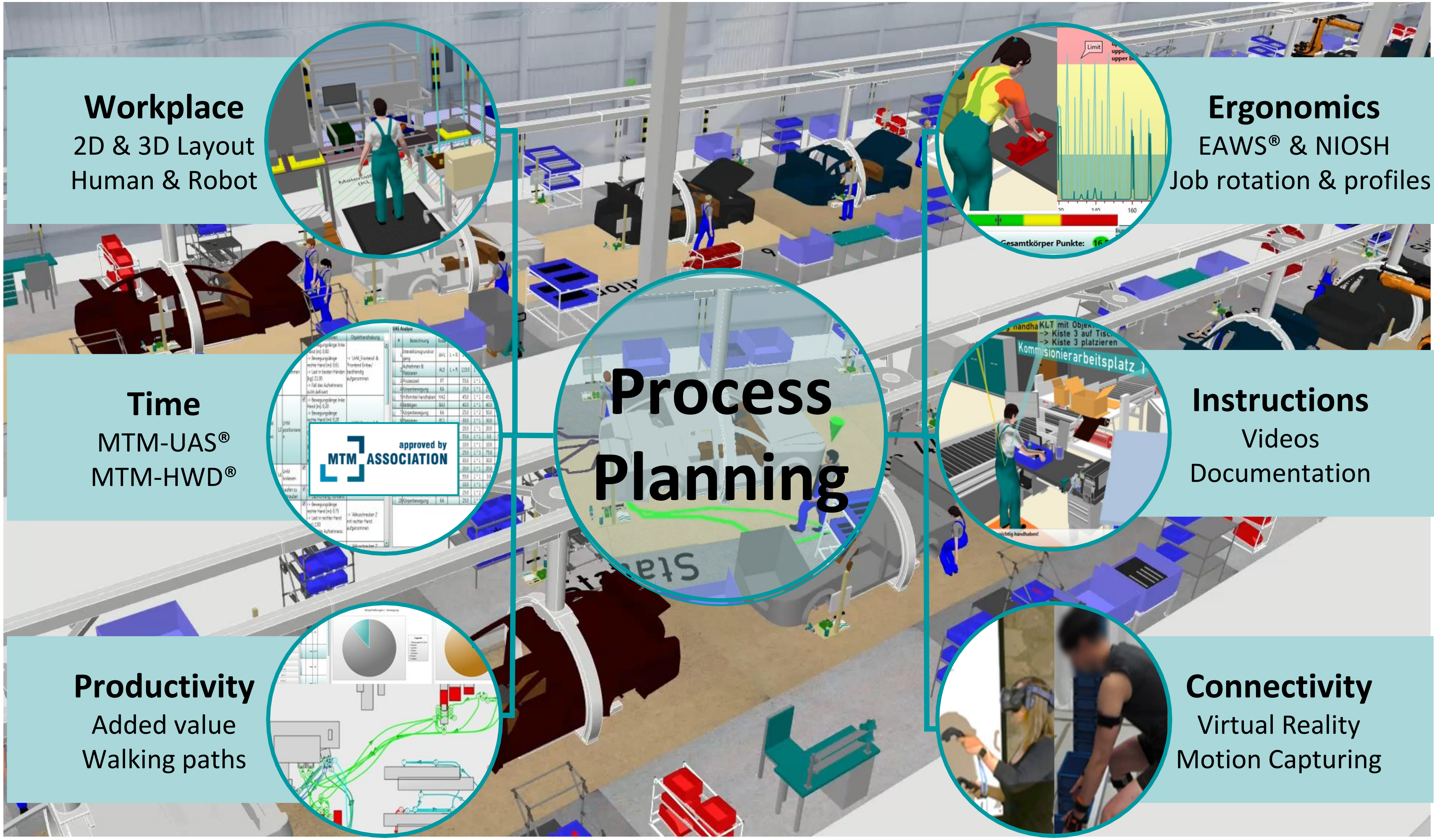
- Robotics
- Interaction
- Risk Assessment

Nvidia Omniverse Connector



- High-End-Rendering
- Data exchange
- Real time collaboration

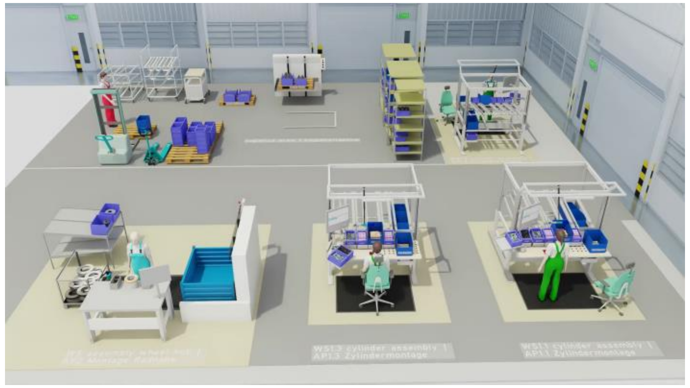
Functionalities ema Work Designer



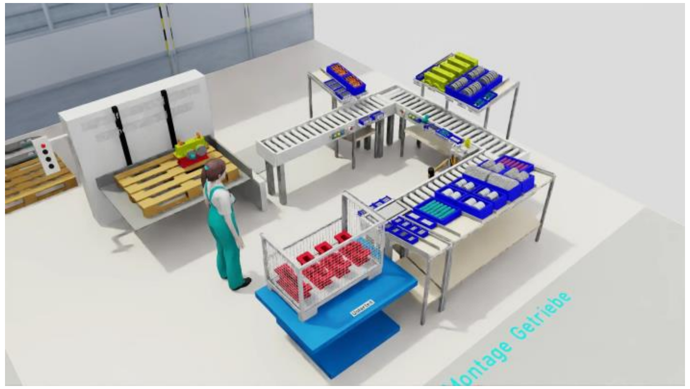
Simulate in every step, shape & scale

Factory level

Logistics

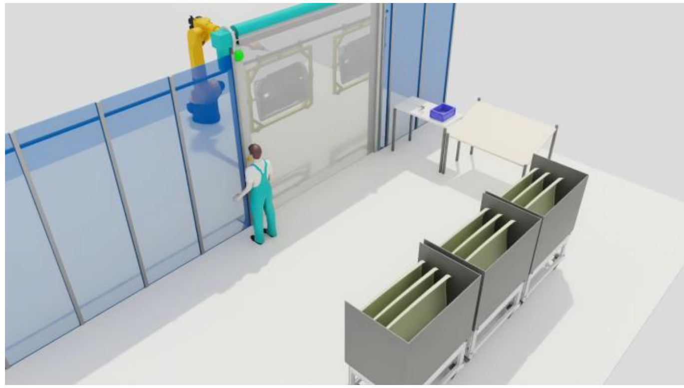


Pre-assembly



Line production

Cell / Workshop production



Specific applications

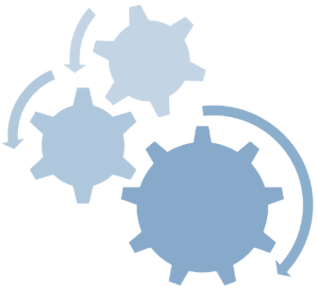
ema Software Suite – Customers & Partners

Motion Generation in ema Work Designer

Process description

Tasks

Motion generator



“Remove reinforcement plates 02 and 04 from container and insert into fixture V08.”

automatic

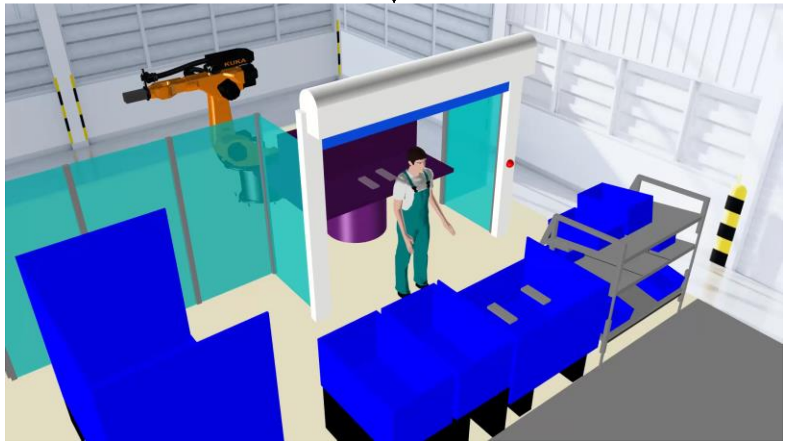
Walk to object
Plate 02 & 04/Container

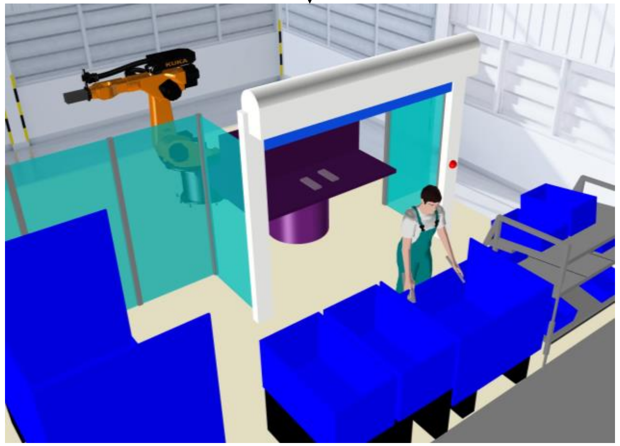
Pick object
Plate 02 & 04/Container

automatic

Walk to target
Device V08

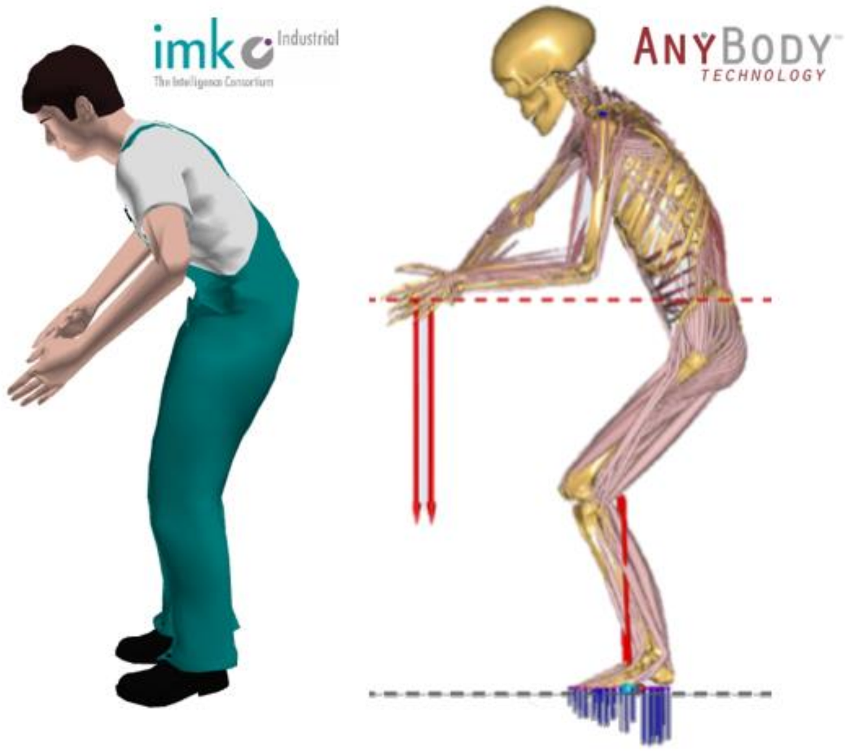
Place object
Plate 02 & 04 in V08





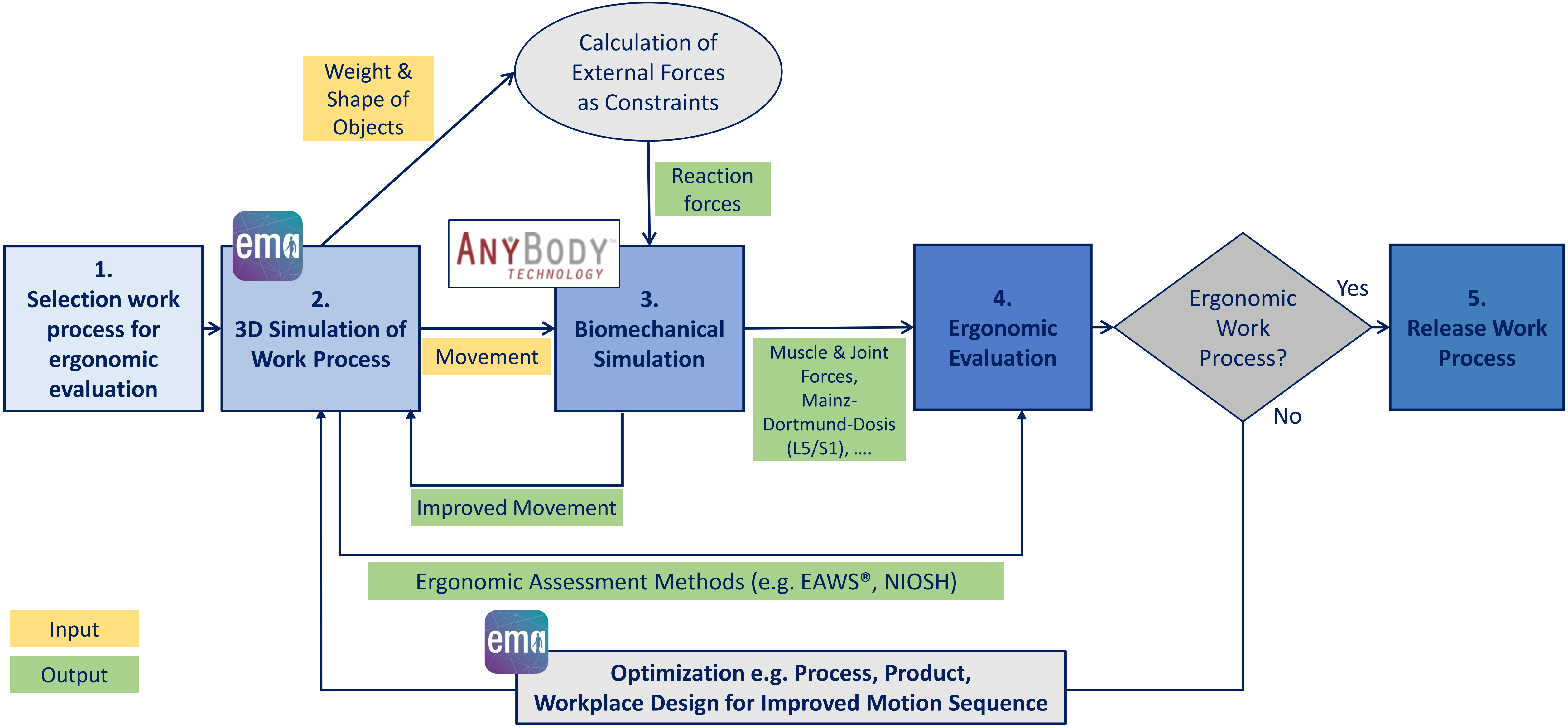
ema2AnyBody – Goals

- Combines advantages of **AnyBody's** biomechanical human model and **ema** human model for 3D process planning
- Data transfer from ema Work Designer to AnyBody to enable **fast biomechanical analyses** with **ema movement sequences** for **industrial use cases**
- Ergonomic analyses enriched with biomechanical parameters for **further analyses in the planning process**

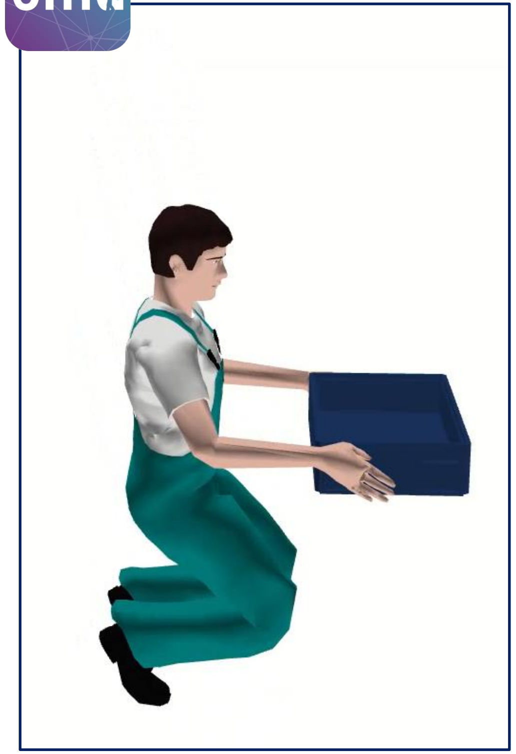


ema2AnyBody – General Workflow Ergonomic Evaluation

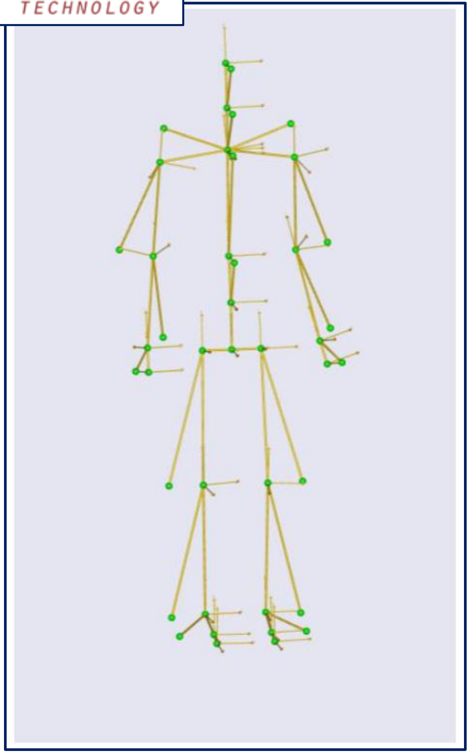
Goal: Design an Ergonomic Work Process



ema2AnyBody – Data Transfer



ema simulation



Movement data from ema in vector model

Transferring the movement data to the AnyBody model

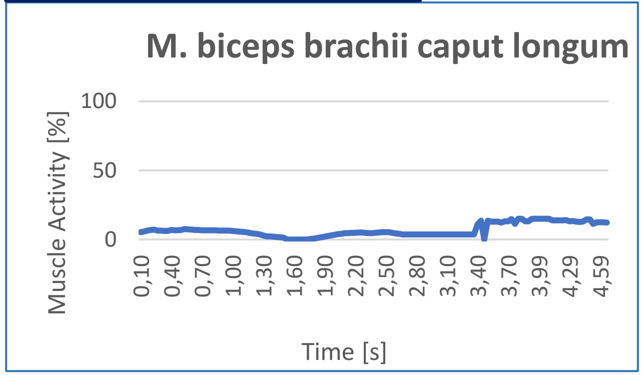
ema simulation with optimized movement

ema2AnyBody – Results Example

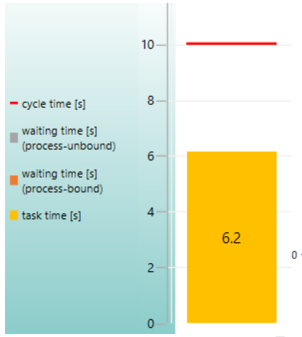
Transparent human model – Motion from ema simulation

Full color human model – Optimized Motion from AnyBody

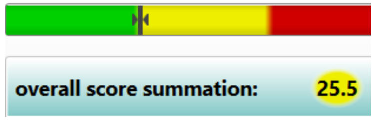
Muscle Activities



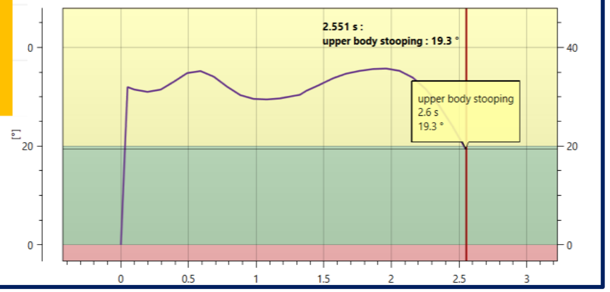
Time analyses



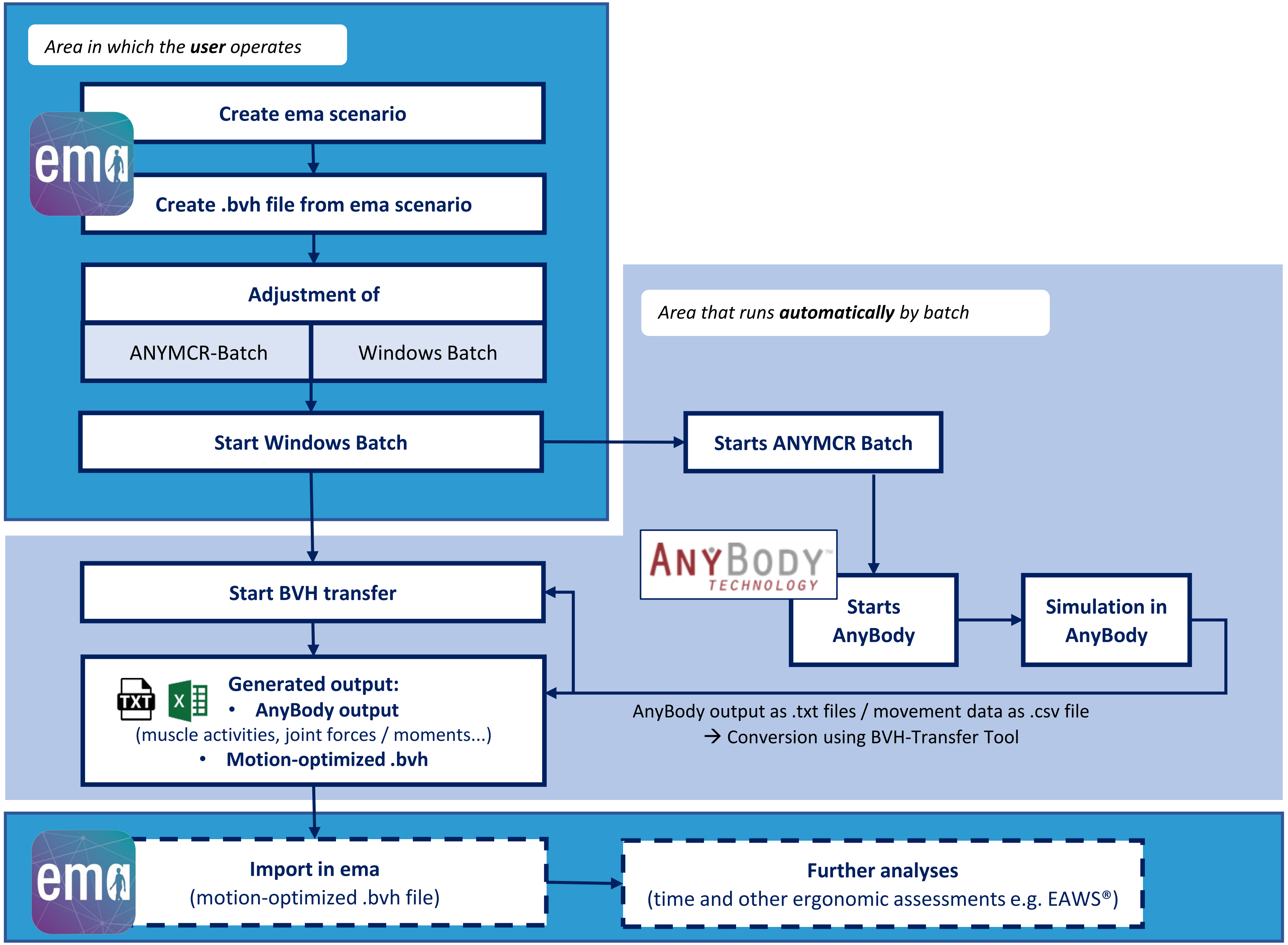
Ergonomics (e.g. EAWS®)



Joint angles

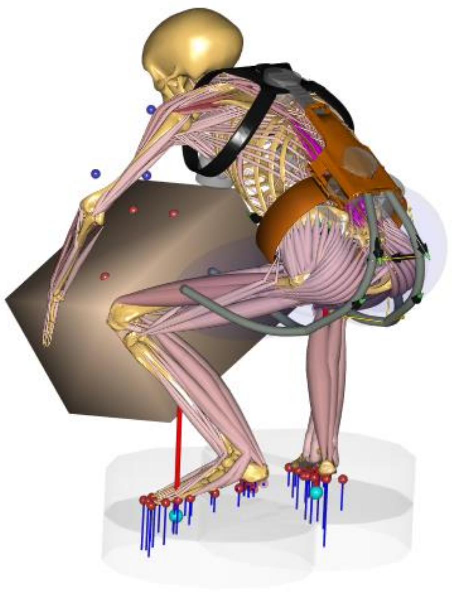


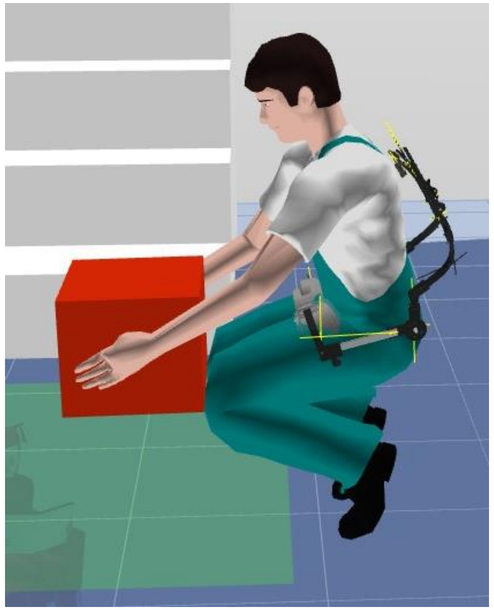
ema2AnyBody – Interface Solution Details

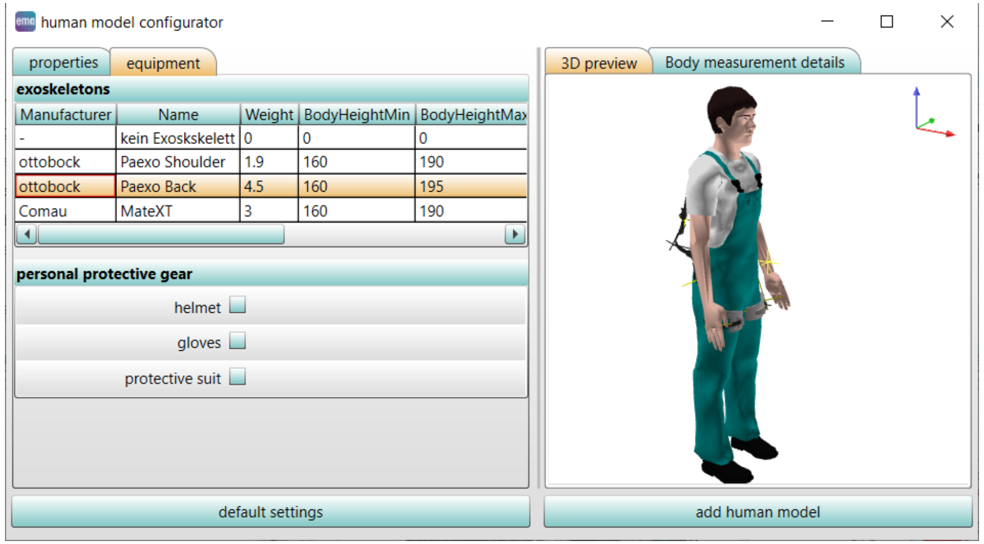


Integration of Exoskeletons in ema Work Designer

- Implementation of **exemplary exoskeletons for shoulder** and **back support**
- Consideration of exoskeleton use in **ergonomic assessment**







	evaluation results without exoskeleton	evaluation results with Paexo Back
whole body [pts]	**25.5**	**24.5**
postures sum [pts]	2.5	2.5
action forces [pts]	0	0
manual handling [pts]	23	20
extra points [pts]	0	2
Upper limbs [pts]	**7**	**7**
Σ Force & Frequency & Grip [pts]	1	1
Σ Hand-/Arm-/Shoulder postures [pts]	0	0
Σ Additional factors [pts]	0	0
Σ Duration Points [pts]	6.8	6.8

Conclusions

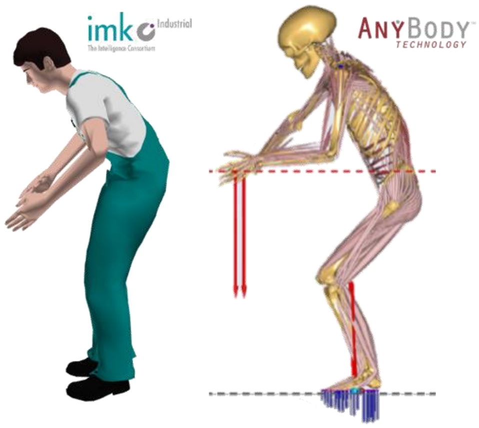
First link between the worlds of biomechanical human modeling and 3D Production Planning

Prototypical interface between AnyBody & ema Work Designer provides enhanced ergonomic evaluations and improved visualisation of movement based on biomechanical simulation

Outlook

Further investigation and development of the interface between ema and AnyBody, e.g.

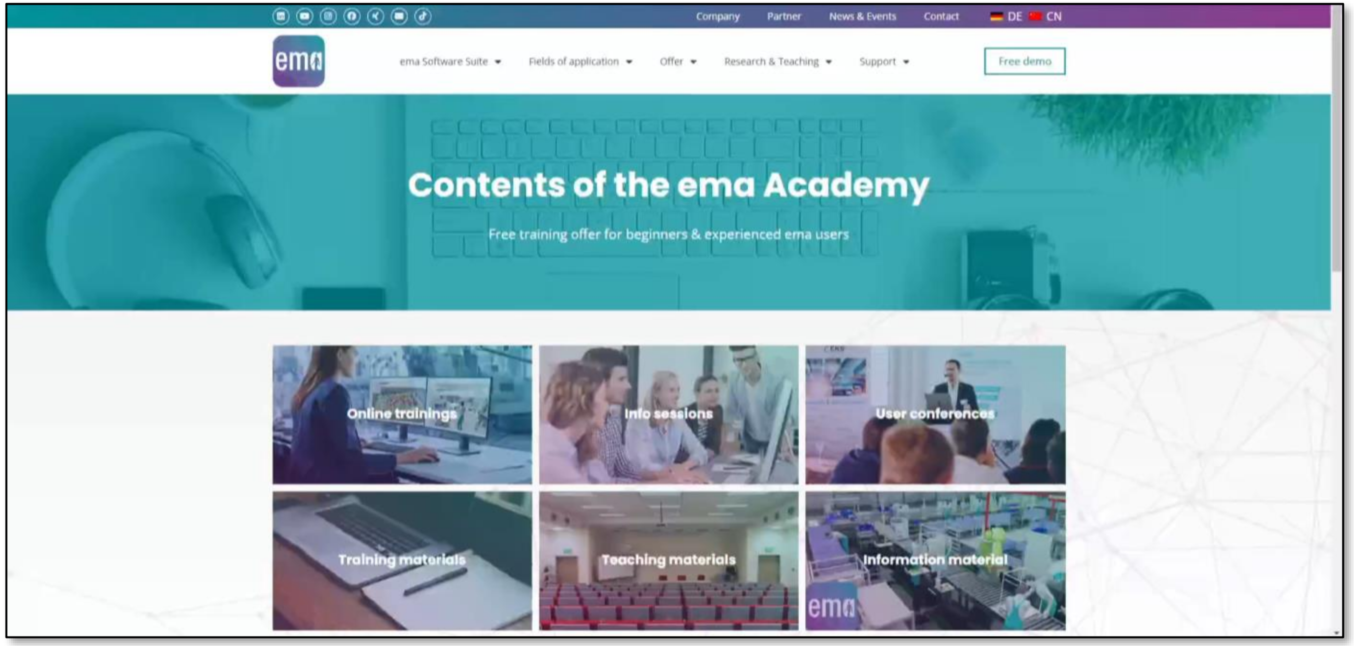
- Consideration of **balance conditions** in ema
- Inclusion of **further key figures from AnyBody** in ema GUI, e.g.
  - Muscle Activities
  - Muscle Forces
  - Joint Moments
- Consideration of **fatigue** for work organisation (break management)



ema Software Suite – Virtual Planning. Real Value.

Interested in ema?

- **More information on our website:** https://imk-ema.com/en/
- **Download demo version for free!** https://imk-ema.com/en/support/downloads/
- **Free tutorials** in our **ema Academy**



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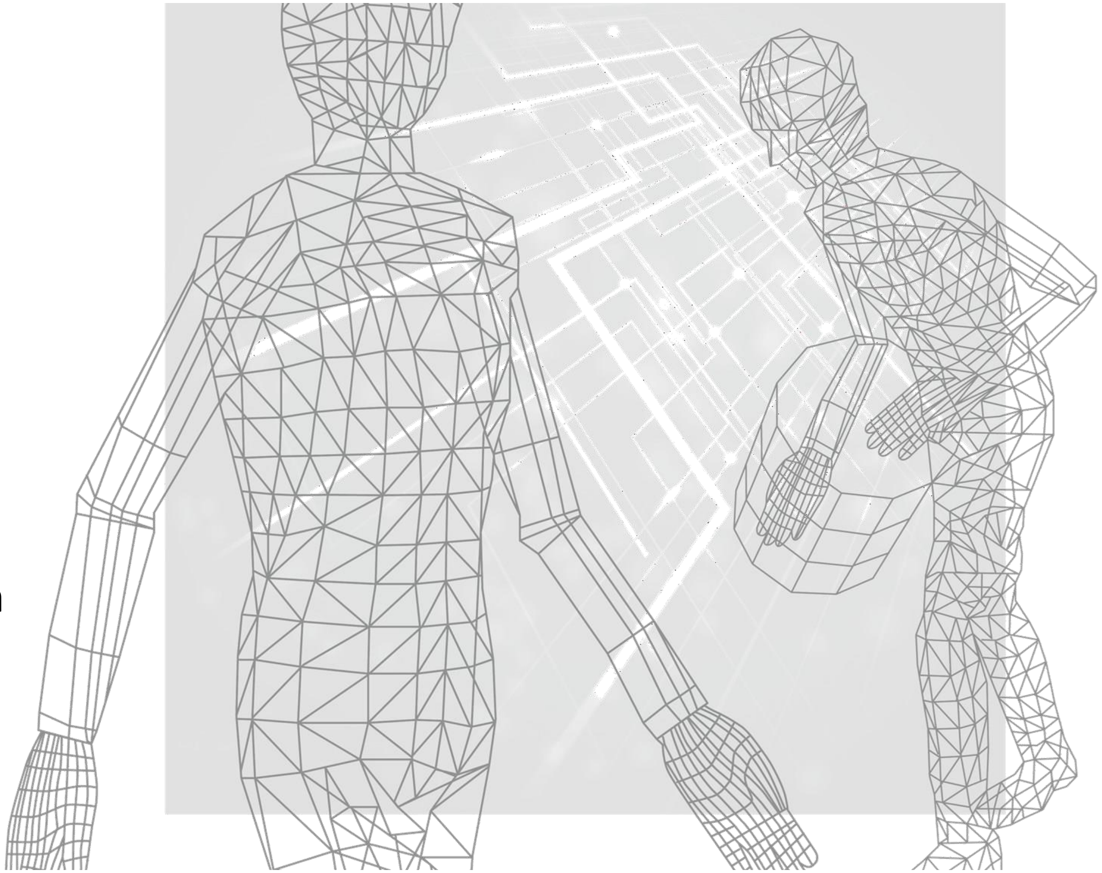


DIGITAL EXONOMICS

GEFÖRDERT VOM

Bundesministerium für Bildung und Forschung

DLR Projektträger

Digitale Arbeitsgestaltung und Ergonomiebewertung für die Anwendung industrieller Exoskelette

Projektpartner

imk industrial competence

the captury

Fraunhofer IPA

OTH Ostbayerische Technische Hochschule Regensburg

Assoziierte Partner

DAIMLER TRUCK

Mercedes-Benz

DB

ottobock.

HUNIC

Universitätsklinikum Tübingen Institut für Arbeitsmedizin, Sozialmedizin und Versorgungsforschung

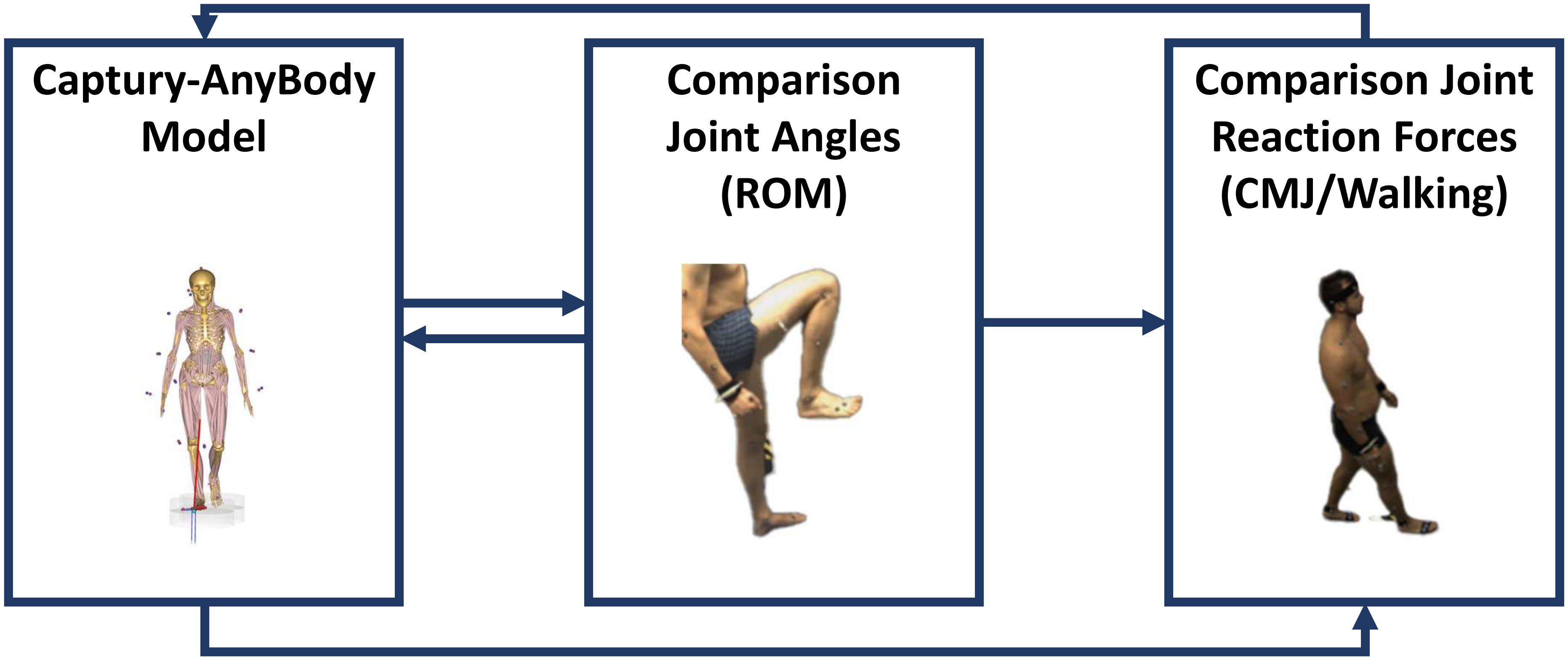
unrestricted grant by SÜDWESTMETALL

AnyBody Technology

ASKLEPIOS Klinikum Bad Abbach

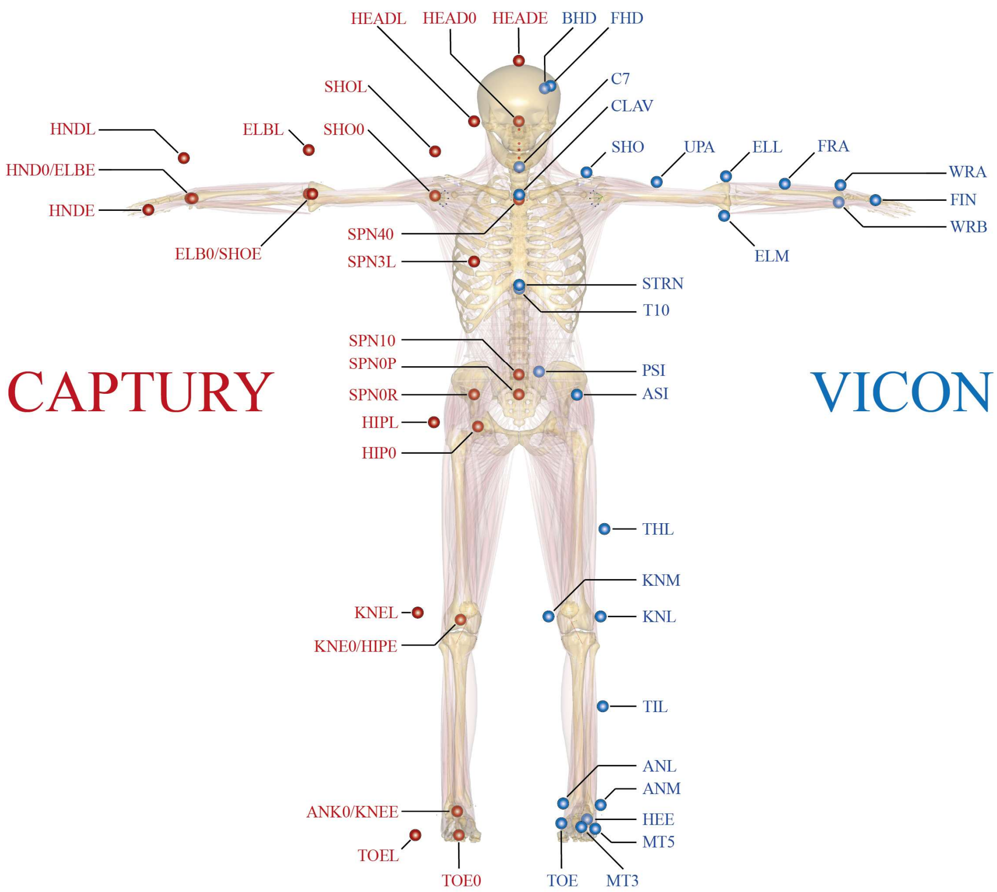
Overview

DIGITAL EXONOMICS



Captury – AnyBody Model

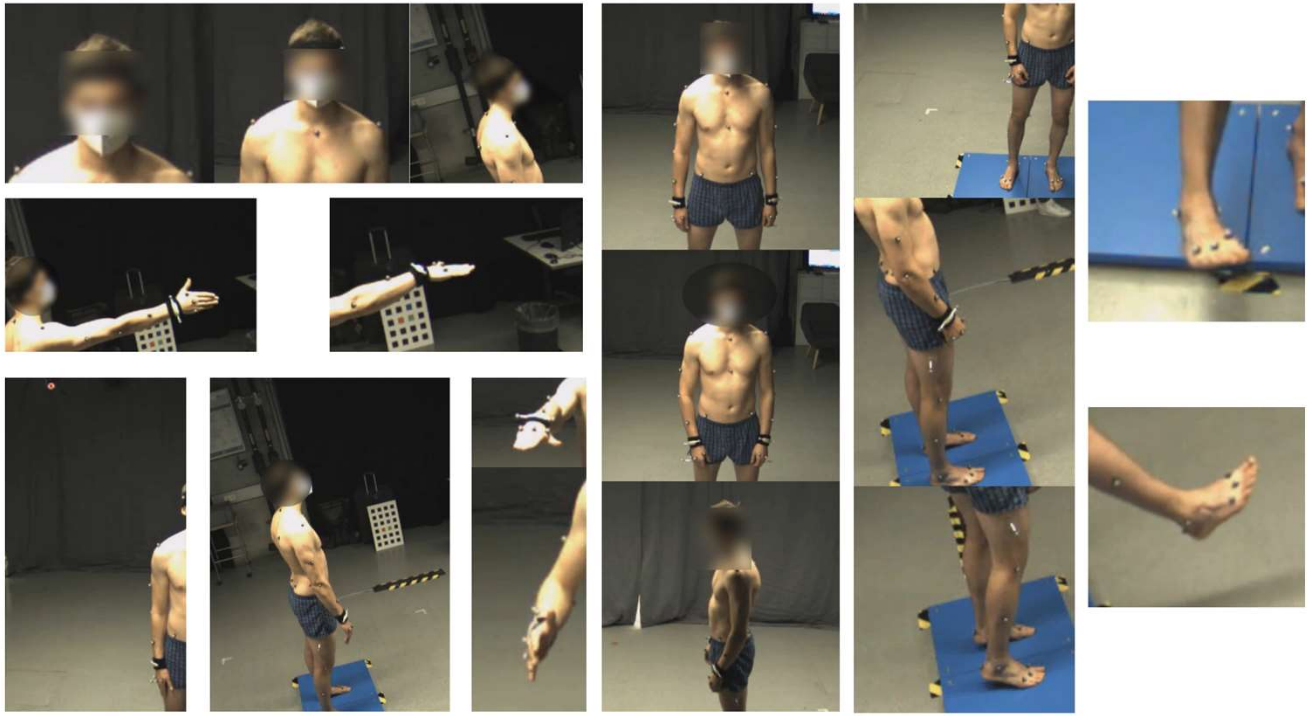
- AnyBody-Model based on the ‘PlugIn-Gait’ model of the AMMR (v. 2.4.4)
- Virtual marker set:
  - One marker at the segment origin
  - One marker at the segment end point
  - One marker with fixed lateral offset relative to the origin
  - →C3D interface in AnyBody
- No ‘ParameterIdentification’:
  - Calculation of segment lengths from C3D input
  - End segments (head, hand, foot) need to set manually
- Limitations:
  - High sensitivity regarding load time position
  - Unrealistic ankle flexion in some cases (too much flexion)



Comparative study: Vicon vs Captury kinematics in AnyBody

DIGITAL EXONOMICS

- Experimental protocol
  - 18 subjects (12 m, 6 w)
  - 17 ROM movements, 3x per DOF



Marker-based Motion Capture

- 12 VICON cameras
- 240 Hz
- 53 markers

Marker-less Motion Capture

the captury

- 8 machine vision cameras
- 60 Hz
- Resolution: ≈1px/cm
- CapturyLive v.250

Comparative study: Vicon vs Captury kinematics in AnyBody

DIGITAL EXONOMICS

- Modelling and Data Analysis

Marker-based Motion Capture

Marker-less Motion Capture

the captury

ANYBODY TECHNOLOGY

- Simulation: 60 Hz
- Kinematics from C3D file (physical marker set)

Joint angles from musculoskeletal model

ANYBODY TECHNOLOGY

- Simulation: 60 Hz
- Kinematics from C3D file (virtual marker set)

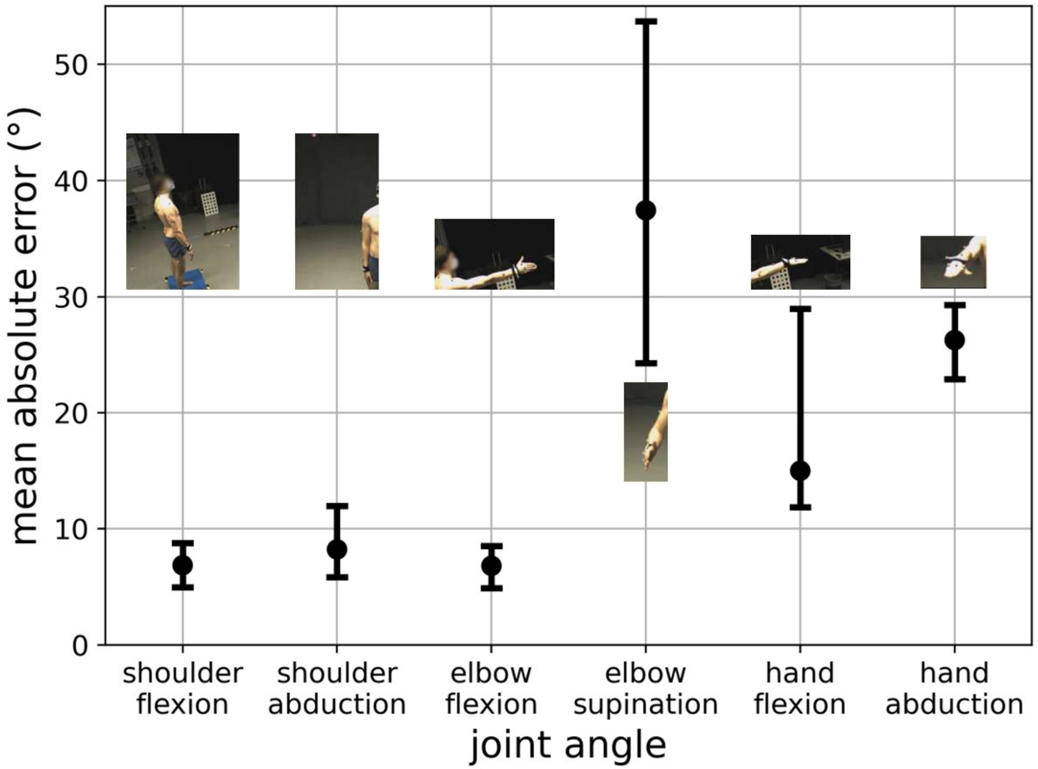
python

- MAE
- MAE_{ROM}
- Pearson r
- R^2

Comparative study: Vicon vs Captury kinematics in AnyBody

DIGITAL EXONOMICS

- Upper extremity

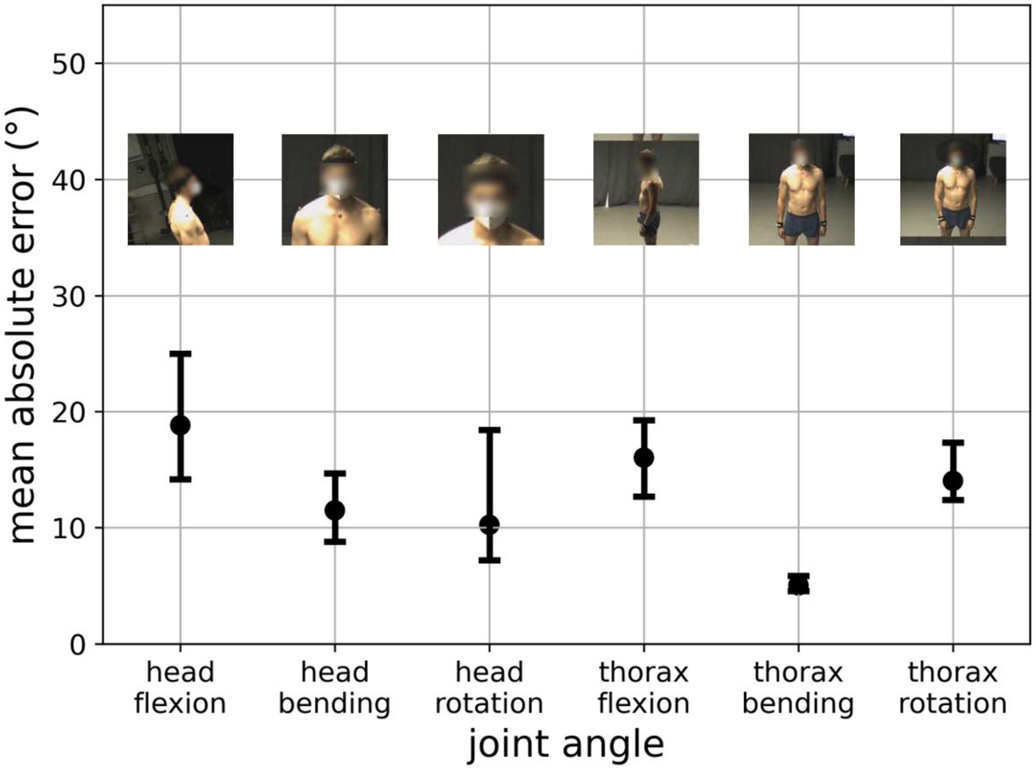


MAE and confidence interval for the upper extremity

- High agreement for shoulder flexion/abduction and elbow flexion
- Deficits in palm tracking: large deviations in elbow pronation and hand abduction
- Hand flexion: inconsistent tracking quality
    - Works well for some cases
    - High errors for some cases

DIGITAL EXONOMICS

- Head and thorax



MAE and confidence interval for head and thorax

- Deviation in head kinematics due to Vicon headband (different wearing style + movement artifacts)

→ High correlation: Generally good tracking quality coupled with constant offset caused by headband position

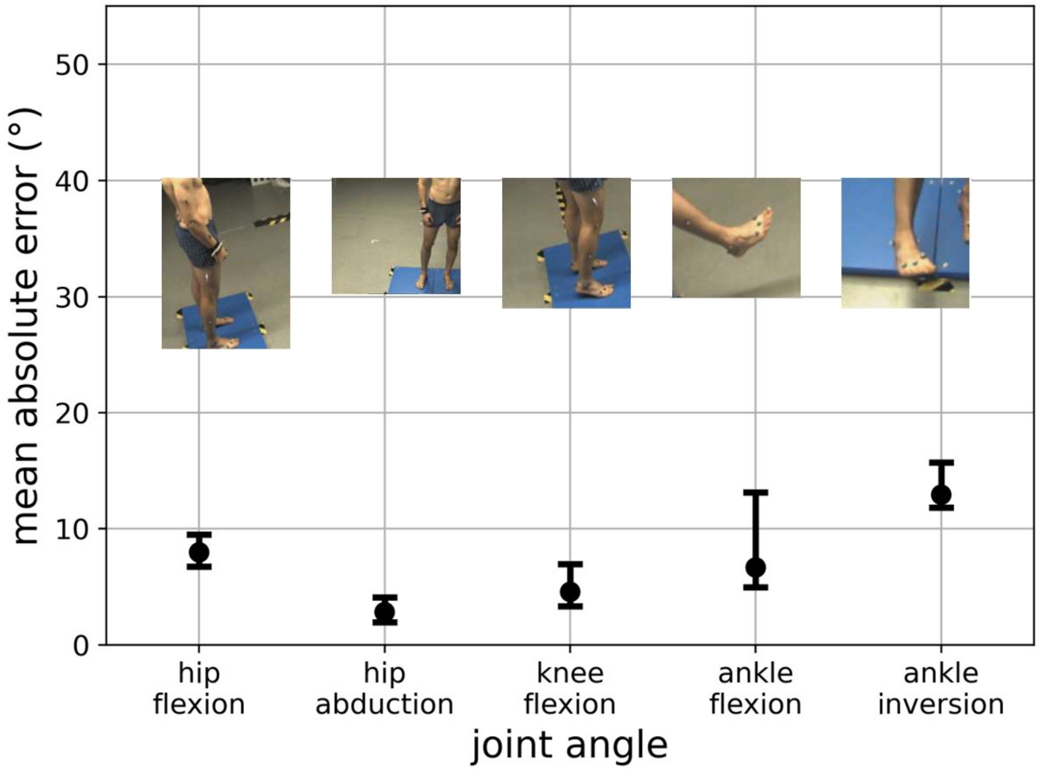
- Pelvis/Thorax flexion/rotation is transferred to the hip

→ Low deviation if hip and thorax joint are combined

Comparative study: Vicon vs Captury kinematics in AnyBody

DIGITAL EXONOMICS

- Lower extremity



MAE and confidence interval for the lower extremity

- Small to very small deviations in combination with high *r* and R^2 values for the lower extremities
- RMSE of lower extremities within range of inertial[1] or other markerless[2] MoCap systems
- For ankle inversion some motion is probably transferred to hip rotation

[1] Karatsidis et al. (2019), Med Eng Phys
[2] Kanko et al. (2021), J Biomech

Comparative study: Vicon vs Captury kinematics in AnyBody

Conclusion:

- Considerably improved recording conditions
- Some motion is transferred to other joints
- Evaluation only for the AnyBody Modeling System
- Hand tracking needs improvement (already in progress)
- Main joint angles are as good as other non marker-based motion capture systems

Comparative study: Vicon vs Captury kinetics in AnyBody

DIGITAL EXONOMICS

VICON

- Counter Movement Jump (CMJ)
- Walking: 3 different speeds
- 17 subjects

the captury

ANYBODY TECHNOLOGY

- Joint angles
- Joint reaction forces (JRF)
- Ground reaction forces (GRF)

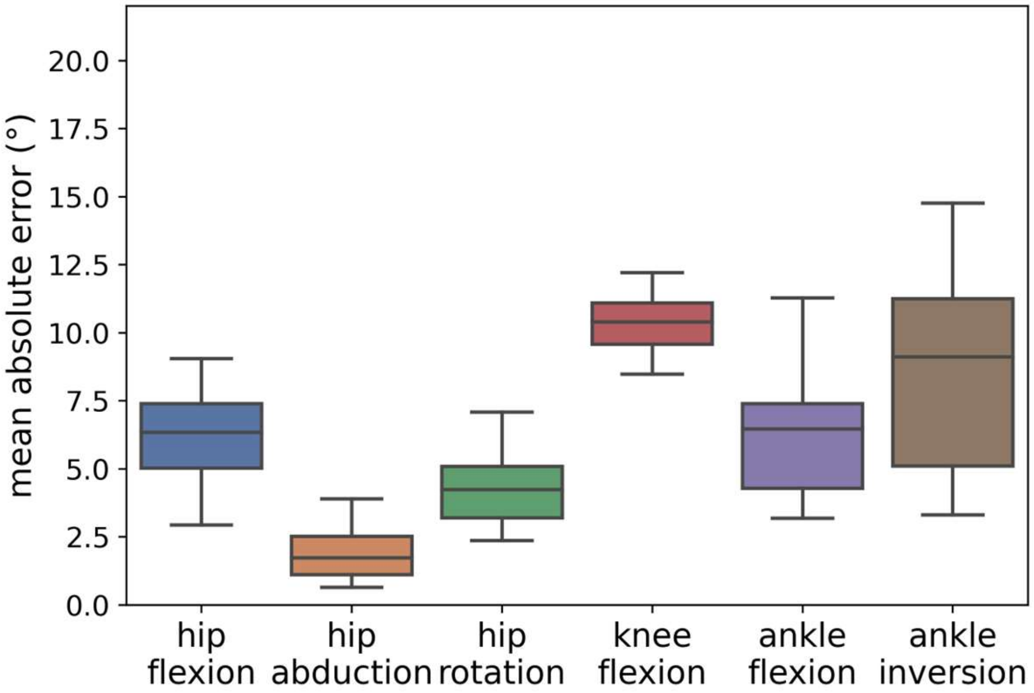
ANYBODY TECHNOLOGY

python™

- MAE
- $MAE_{ROM/MaxF}$
- Pearson r
- Bland-Altman

Comparative study: Vicon vs Captury kinetics in AnyBody

- Joint angles during CMJ:



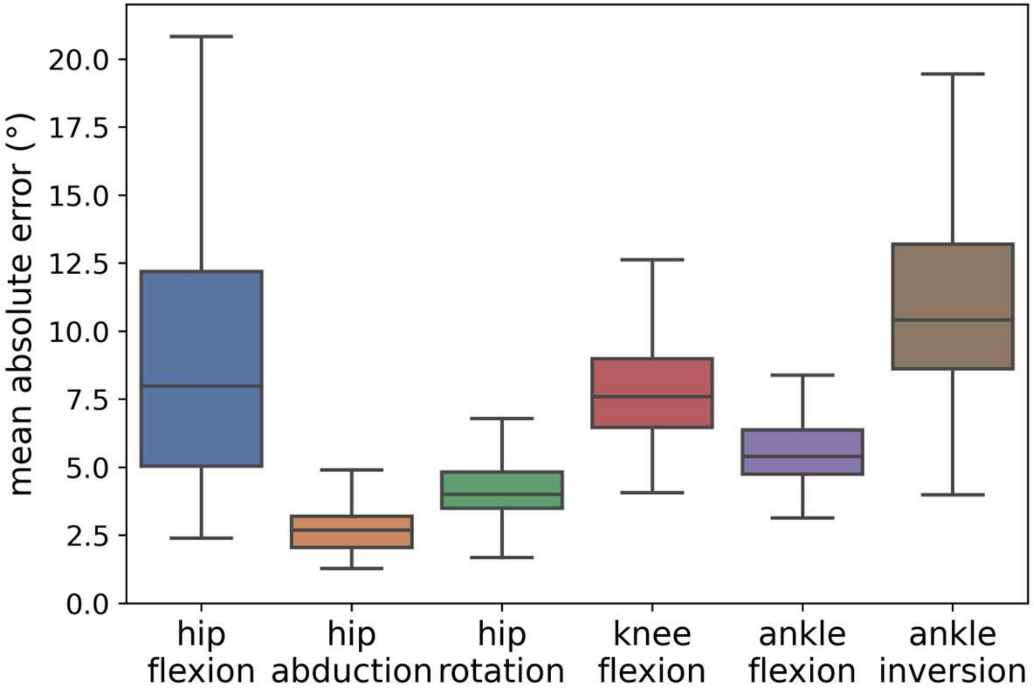
Boxplot MAE joint angles during CMJ

- Similar results to previous (kinematics only) study
- MAE ranges from 1.7° (hip abduction) to 10.4° (knee flexion)
- Mostly (very) high correlation except hip rotation
- Captury overestimates knee flexion

Comparative study: Vicon vs Captury kinetics in AnyBody

DIGITAL EXONOMICS

- Joint angles during walking:



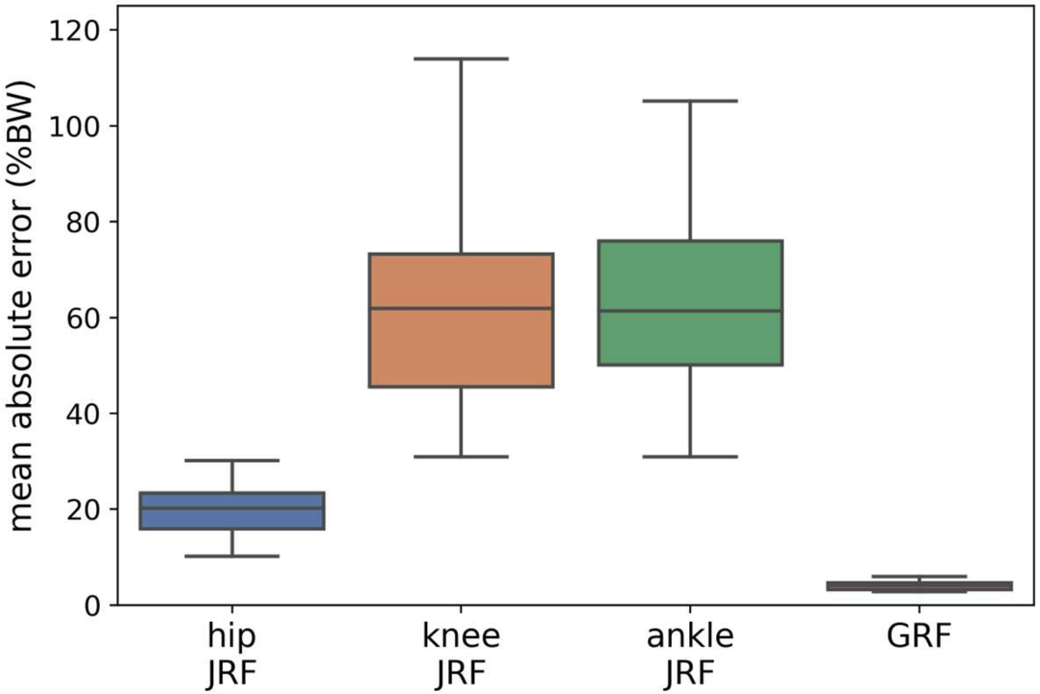
Boxplot MAE for joint angles during walking (medium speed)

- Similar results to previous (kinematics only) study and CMJ
- MAE ranges from 2.4° (hip abduction, slow walking) to 8.5° (hip flexion, fast walking)
- MAE increases with walking speed
- Hip flexion:
  - High deviation
  - Overestimation by Captury
- Captury overestimates knee flexion for small flexion angles

Comparative study: Vicon vs Captury kinetics in AnyBody

DIGITAL EXONOMICS

- JRF and GRF during CMJ:



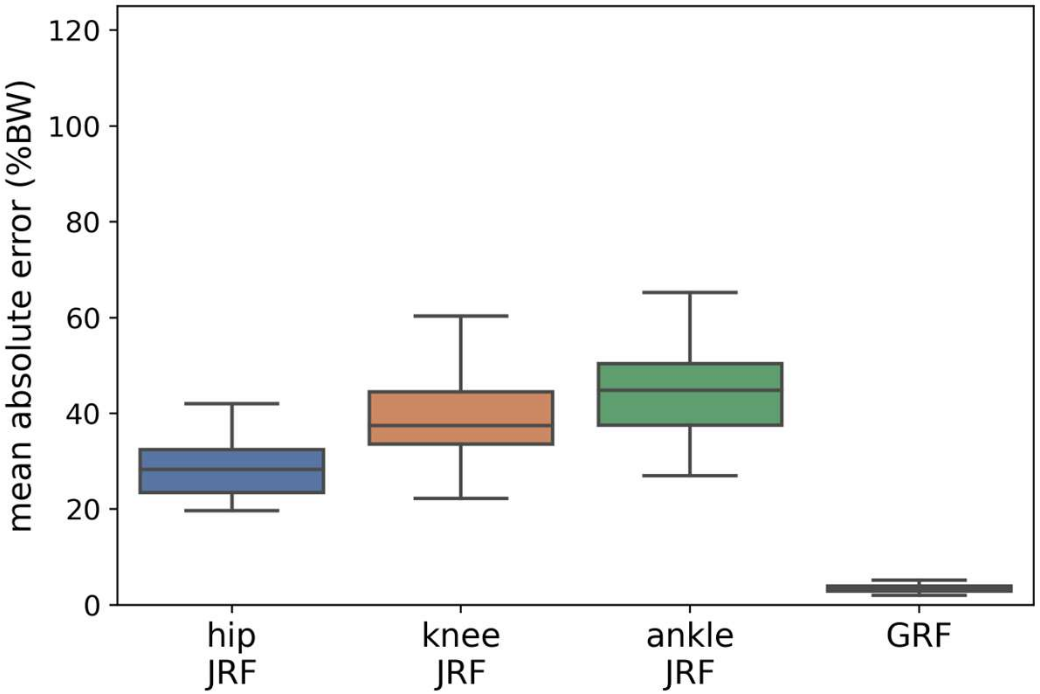
Boxplot MAE for JRF and GRF during CMJ

- MAE for JRF ranges from 20.3 %BW (hip) to 61.9 %BW (knee) at GRF 1.6 %BW
- Relative error ranges from 3.4% (GRF) to 6.4% (ankle)
- r ≥ 0.95 for all parameters
- Captury underestimates peak JRF in the knee and ankle joint

Comparative study: Vicon vs Captury kinetics in AnyBody

DIGITAL EXONOMICS

- JRF and GRF during walking:



Boxplot MAE for JRF and GRF during walking (medium speed)

- MAE for JRF ranges from 23.3 %BW (hip, slow walking) to 57.4 %BW (ankle, fast walking) at GRF 3.2-4.6 %BW
- Relative error ranges from 2.8% (GRF, slow walking) to 7.3% (knee, fast walking)
- r ≥ 0.91 for all parameters/speeds
- Captury overestimates peak JRF in the knee and ankle joint
- Error range increase with walking speed

Conclusion:

- Kinematics comparable with ROM study and literature values and within the accuracy range of marker-based systems
- Overestimation of small knee angles leads to overestimation of peak forces in the knee and ankle joints when walking (at heel strike)
- Generally low relative error (<8%) for joint reaction forces, but deviations for peak forces
- Relative deviation in joint reaction forces within the accuracy range of musculoskeletal models

Comparative study: Vicon vs Captury kinetics in AnyBody

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- Motion Capture model in AnyBody with largely automated data input → Minimizing user error
- Reduced effort during recording with marker-less system
- Accuracy of kinematics and kinetics comparable to literature and other motion capture systems: but deviations for peak JRF

Contact

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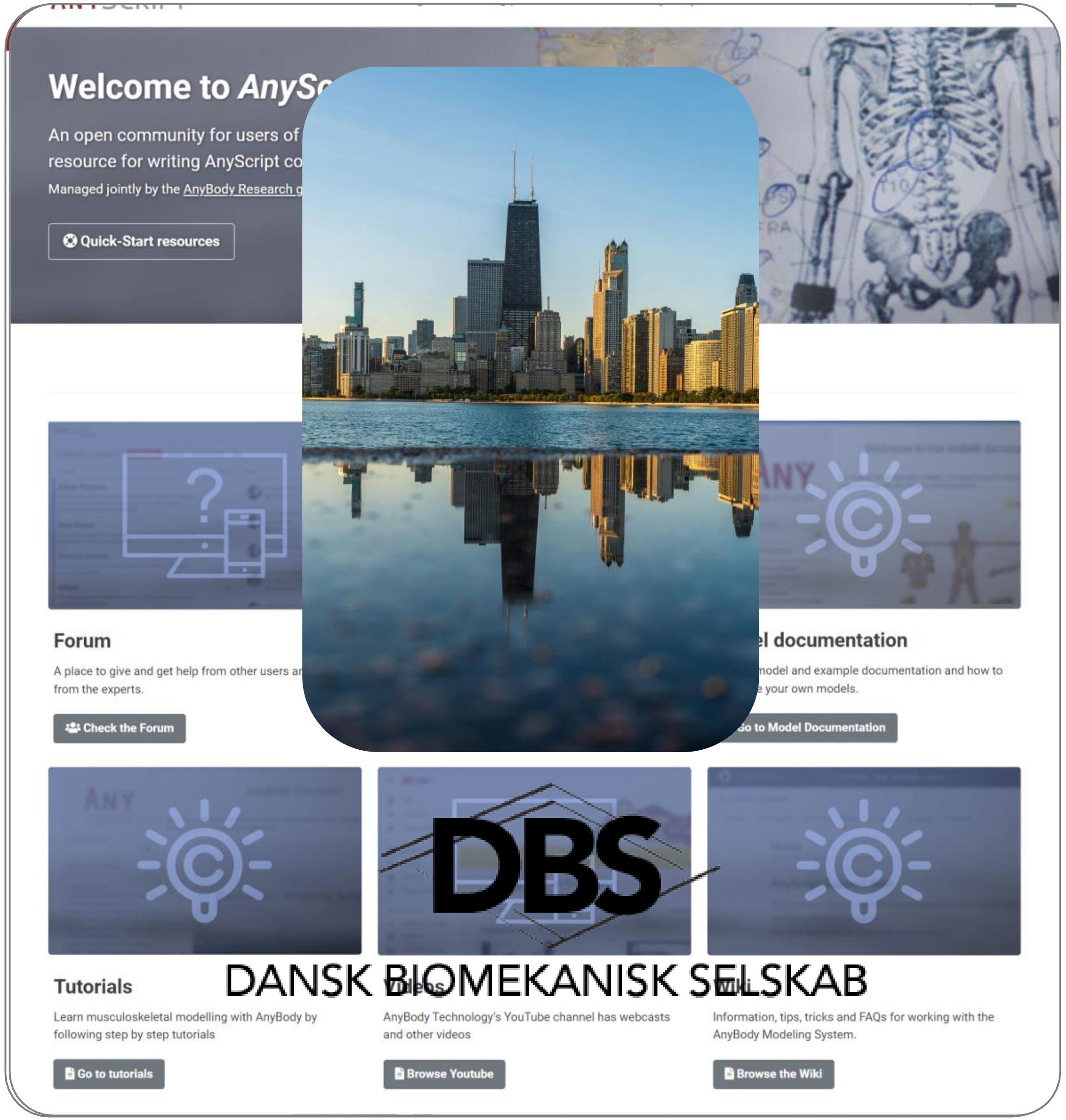
Resources

- **[www.anybodytech.com]**
  - Events, Webcast library, Publication list, …
- **[www.anyscript.org]**
  - Wiki, Blog, Repositories, Forum
- **Events**
  - AnyBody Technology visiting Chicago, IL
    - November 7 - 17, 2024
  - 16th annual meeting of the **Danish Society of Biomechanics** in Roskilde, Denmark.
    - November 22, 2024



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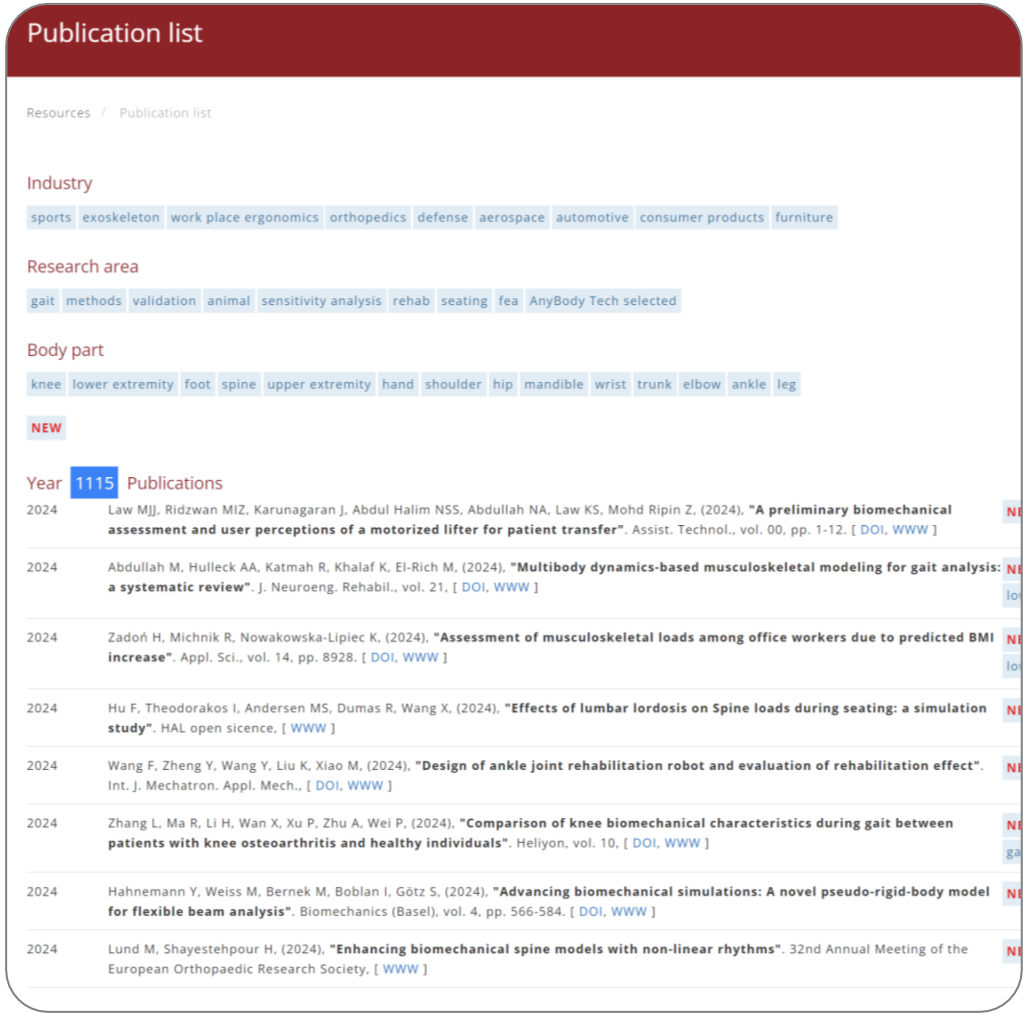

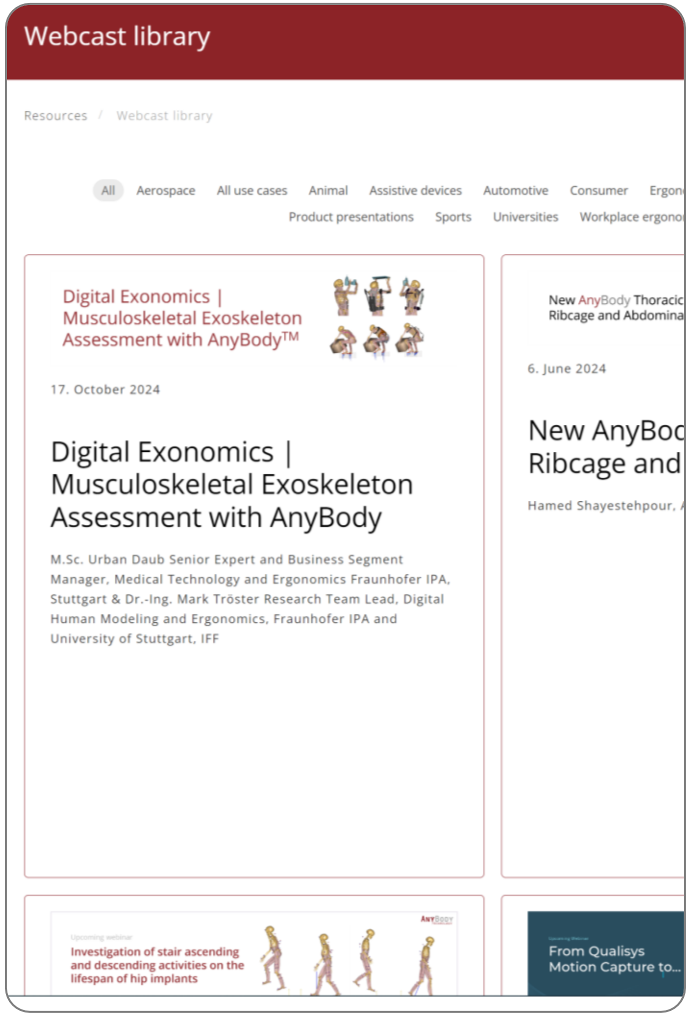

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Questions

Meet us

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Trial version

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Presentation questions

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Thank you for your attention!