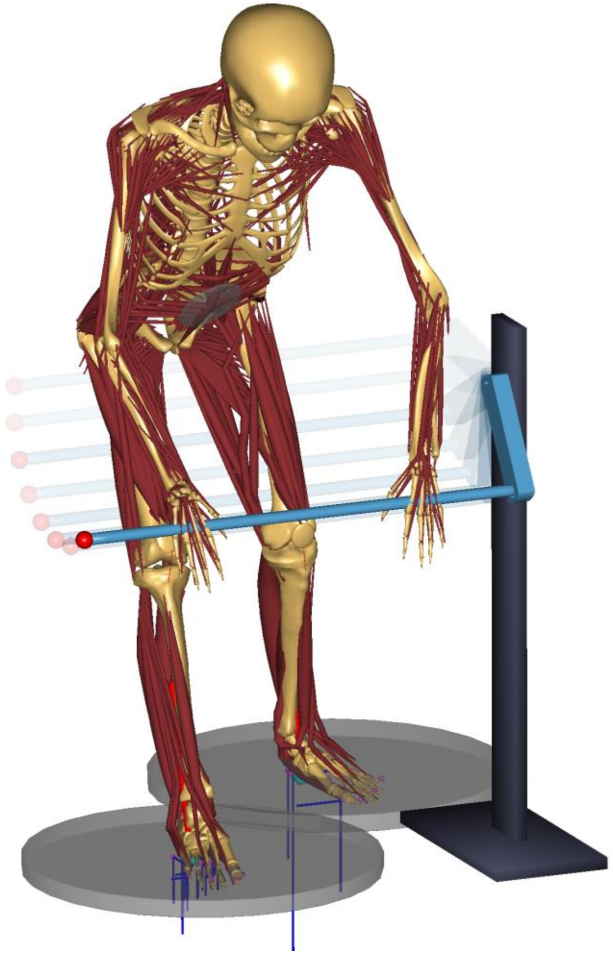
The webcast will start in a few minutes….

Musculoskeletal modelling from scratch

CONCEPTS MADE EASY



Outline

- Introduction by the Host
- Musculoskeletal modelling from scratch - *concepts made easy*
    - *Webcast and demonstration*
- Final words from the host
- Questions and answers

Ananth Gopalakrishnan
(Presenter)

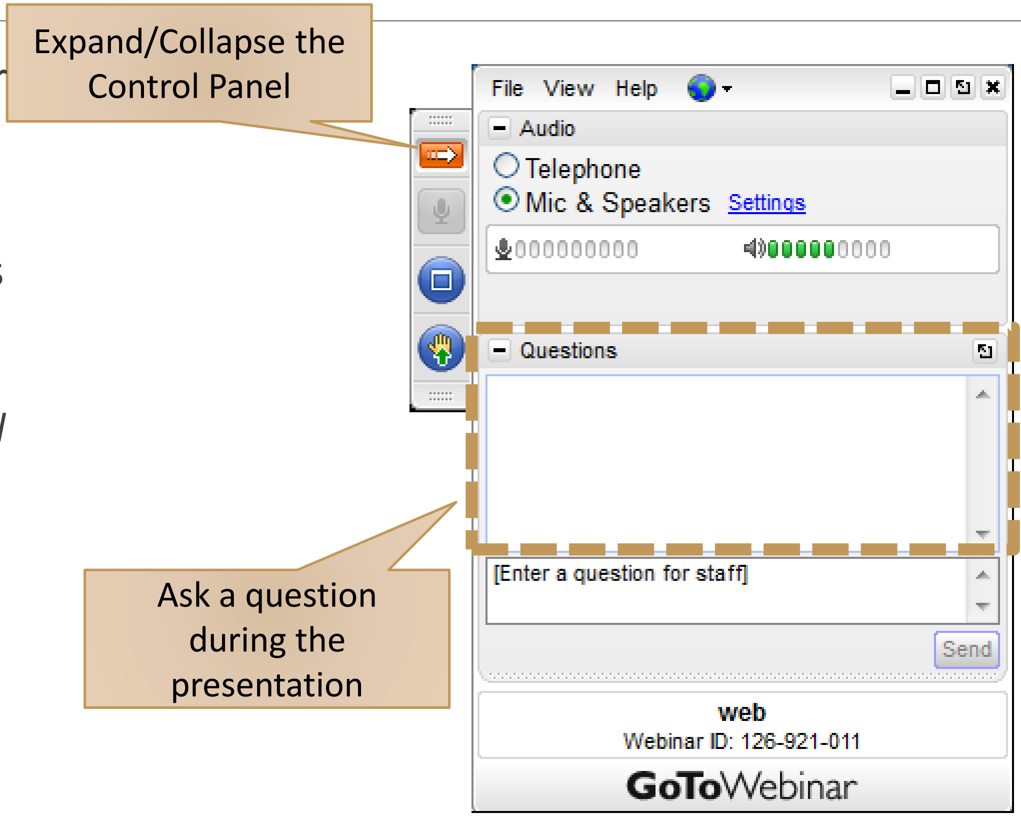
Pavel Galibarov
(Host)

Control Panel

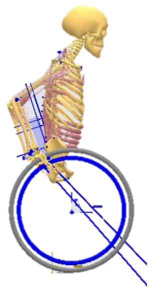
The Control Panel appears on the right side of your screen.

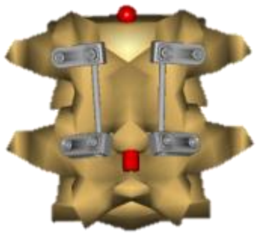
Submit questions and comments via the Questions panel.

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



Who is AnyBody?



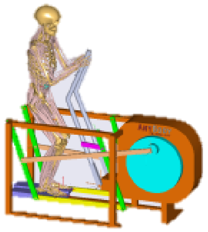


AnyBody Technology
(Aalborg, DK; Boston, US)

- *AnyBody Modeling System*
- *Licenses, Training, Support*
- *Consulting*

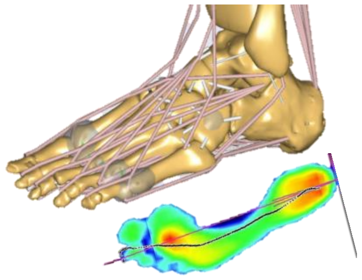
AnyBody Research Group

- *DK: Aalborg University - Prof. Rasmussen*
    - *Biomechanics, Ergonomics, Sport, Automotive*



- *US: Colorado School of Mines – Prof. Petrella*
    - *Biomechanics, Orthopedics, Sport*

- *GER: OTH Regensburg – Prof. Dendorfer*
    - *Biomechanics, Orthopedics, Gait*



What is AnyBody?

A nyBody
M odeling
S ystem

A nyBody
M anaged
M odel
R epository

- Software product/tool

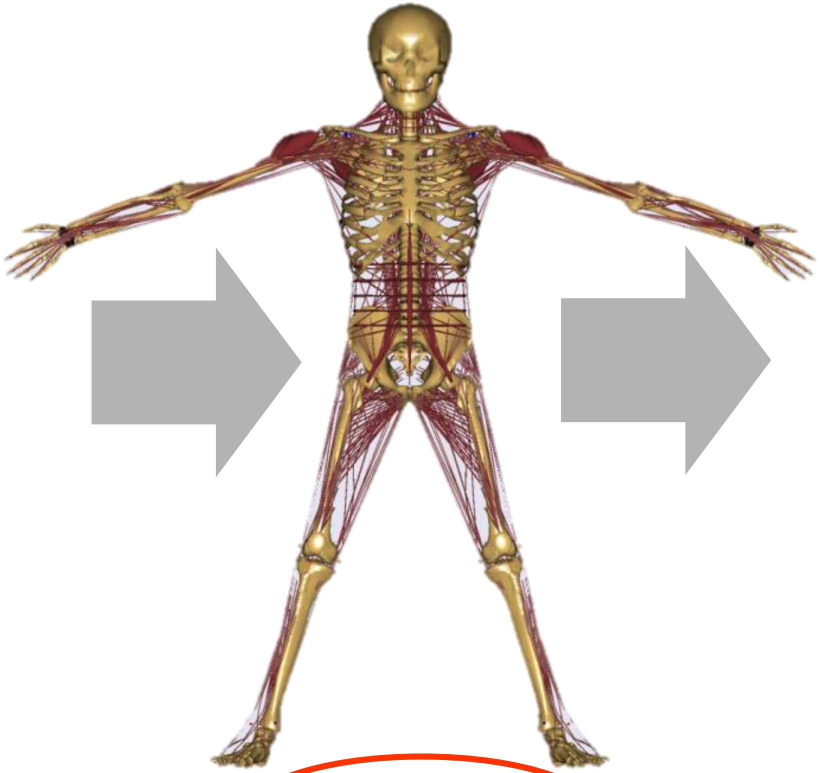
- Body Model

- Library of applications

Musculoskeletal Simulation

Input

Activity/
Motion



Body Model

Bones

Joints

Muscles

Ligaments

Output

Muscles:
forces, activity, power
Joints:
forces, moments,
...

Questions for Inverse Dynamics?

ReWalk Eksokeleton,
Argo Medical Technologies

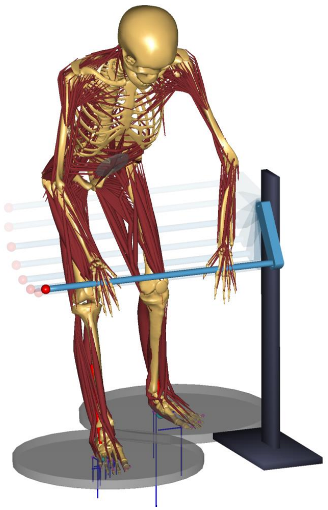
How much external support?

www.commons.wikimedia.org

Design load for daily activities?

pixabay.com

Best design for performance?



Musculoskeletal Modelling From Scratch

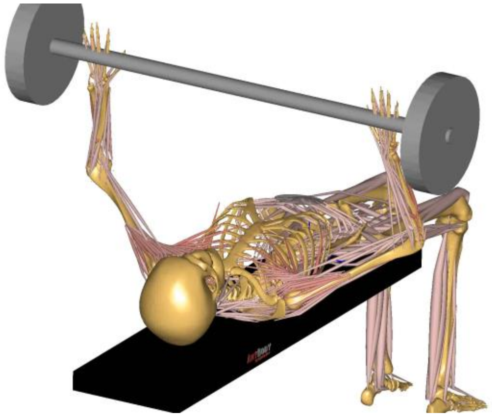
CONCEPTS MADE EASY!

Introduction

- Musculoskeletal model
  - Bones → Rigid segments
  - DOFs → Mechanical joints
  - Muscles → Cable actuators

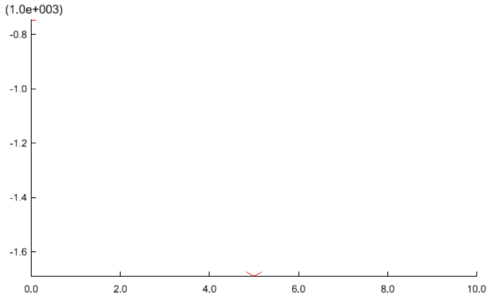
Introduction

- Musculoskeletal model
  - Bones → Rigid segments
  - DOFs → Mechanical joints
  - Muscles → Cable actuators



- Inverse Dynamic simulation
  - Input: Motion data
  - Output: Muscle and joint reaction forces

Individual muscle force



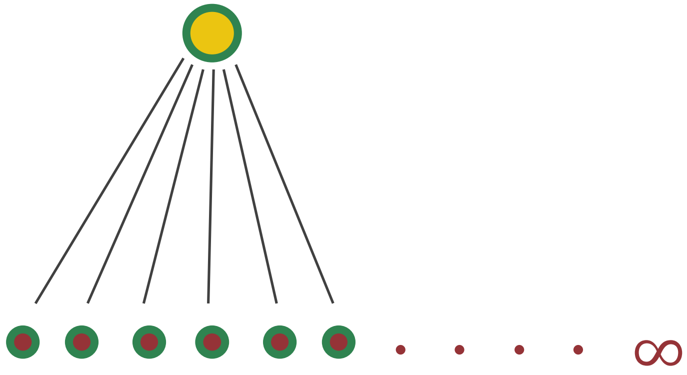
Inverse Dynamics

Motion Data

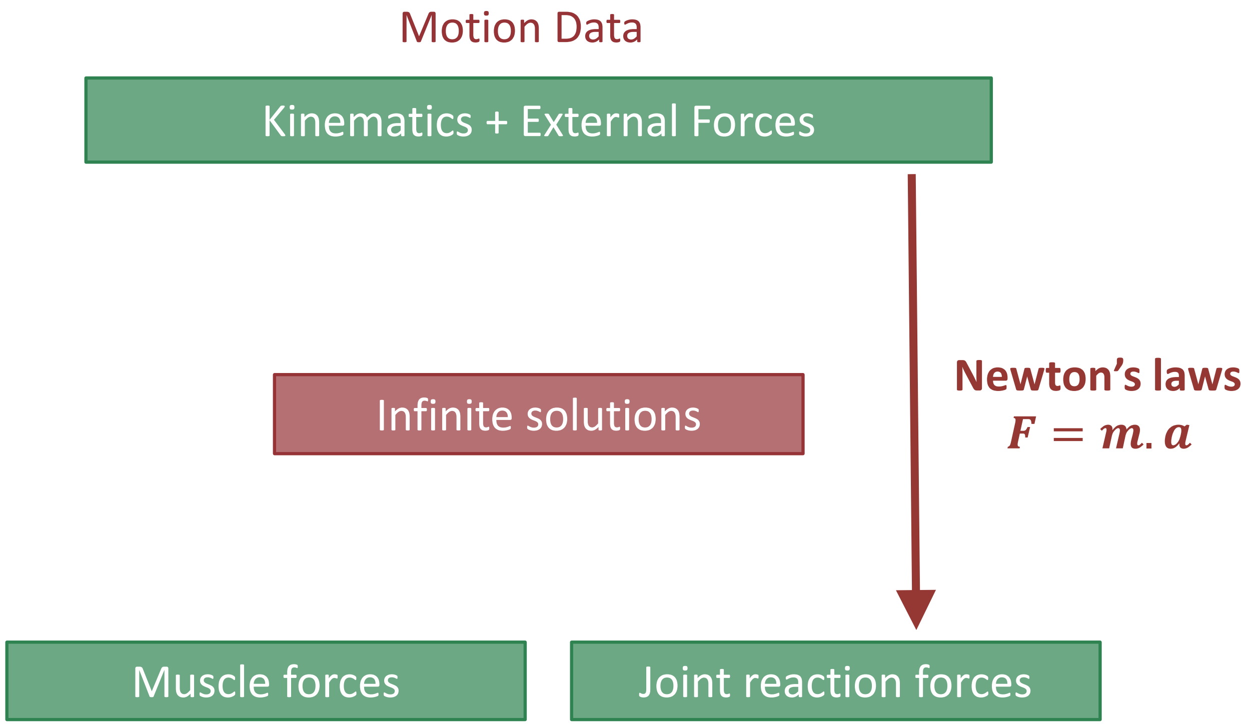
Kinematics + External Forces

Inverse Dynamics

Given Motion

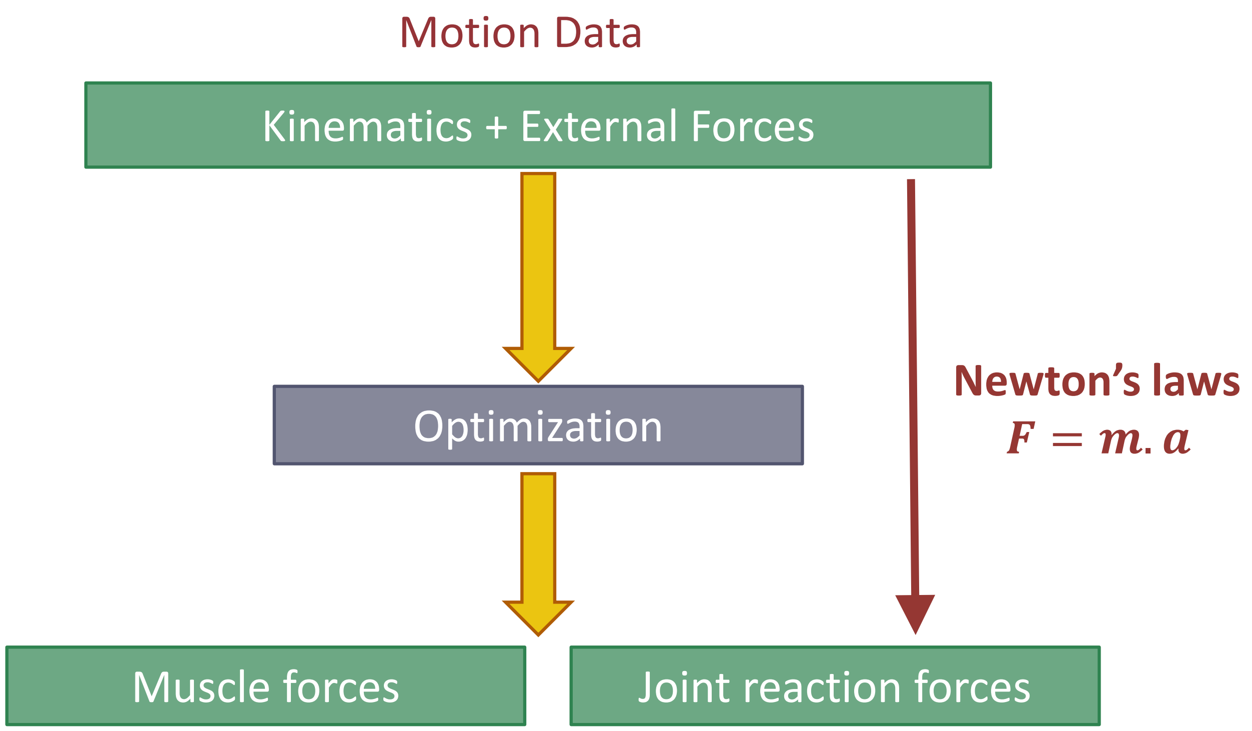


Muscle force
coordination strategies



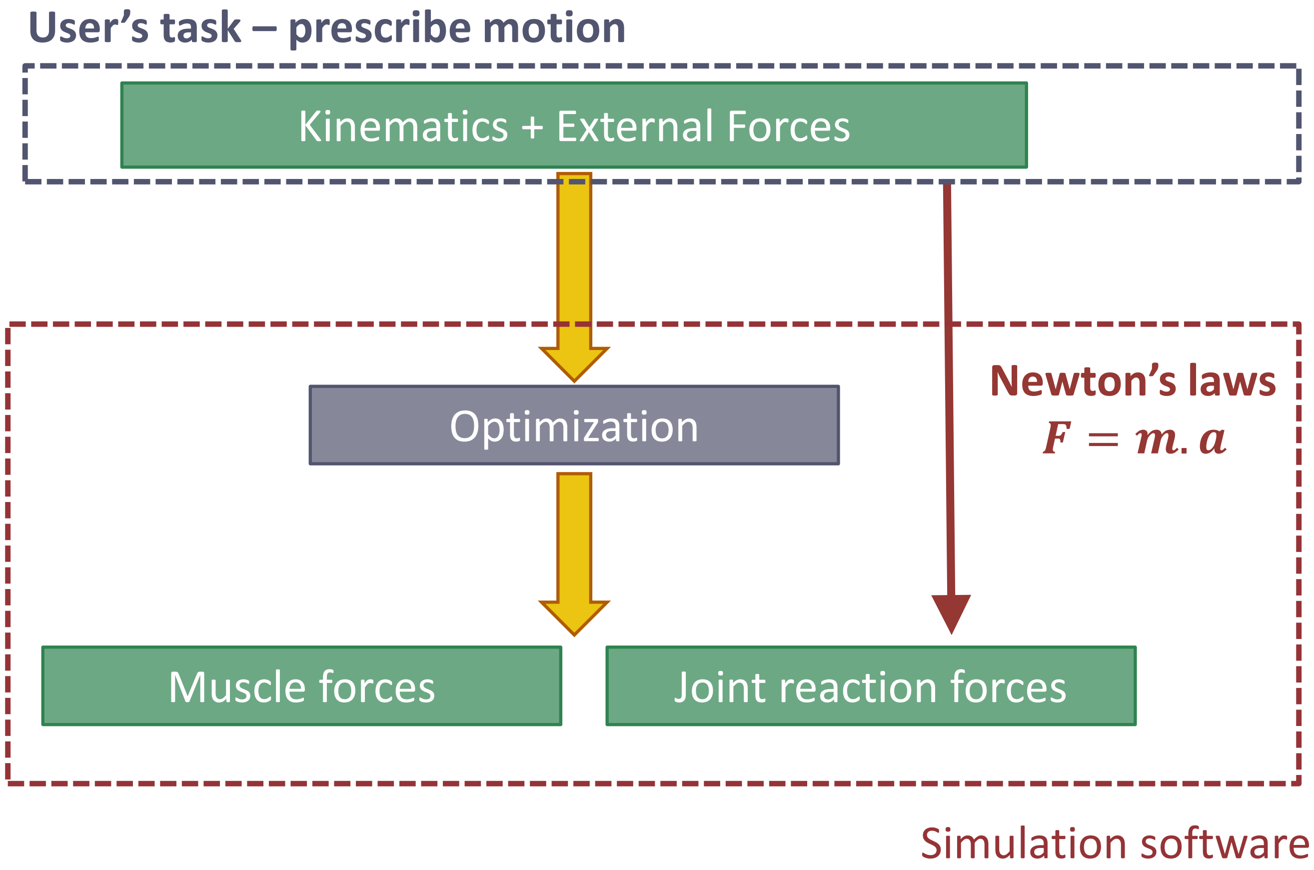
Inverse Dynamics

- Webcast 'Man-machine simulations'
    - 15th March 2016



Inverse Dynamics

- Focus of this webcast
  - Kinematic aspects of modelling

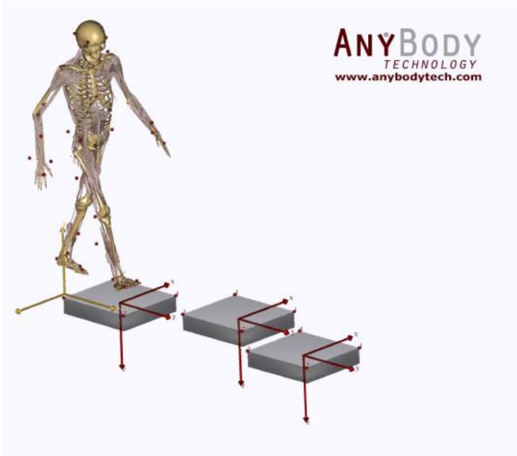


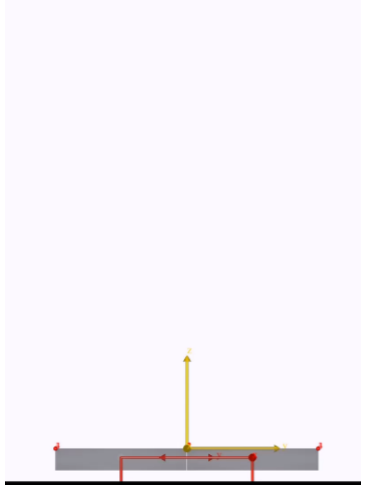
Kinematics

Fully measured
e.g, full MoCap

Partially measured

No exact data, Only task requirements known





Kinematics

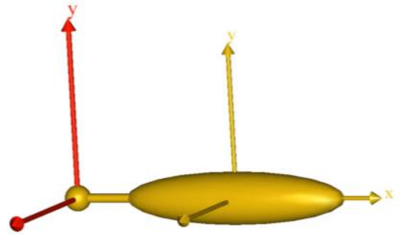
Fully measured
e.g, full MoCap

Partially measured

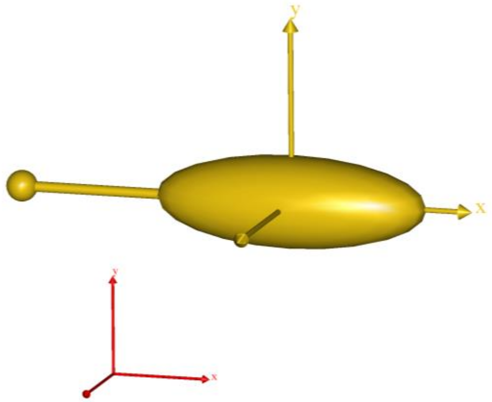
No exact data, Only task requirements known

- Three modelling scenarios
  - ∴ Underlying simulation concepts must also be different?
- Just two core concepts
  - Govern model kinematics in the three scenarios

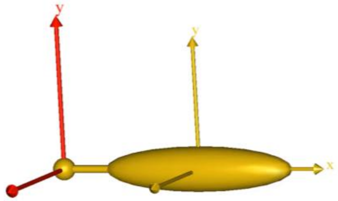
Agenda



Core Concepts: Measures and Drivers



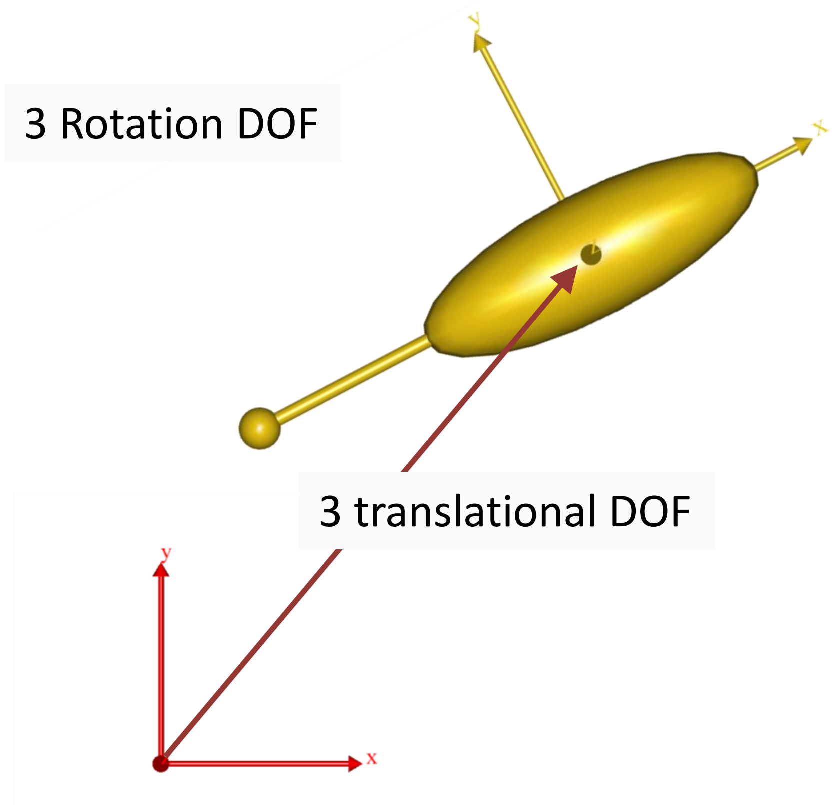
Revolute Joint



Segment suspended in space

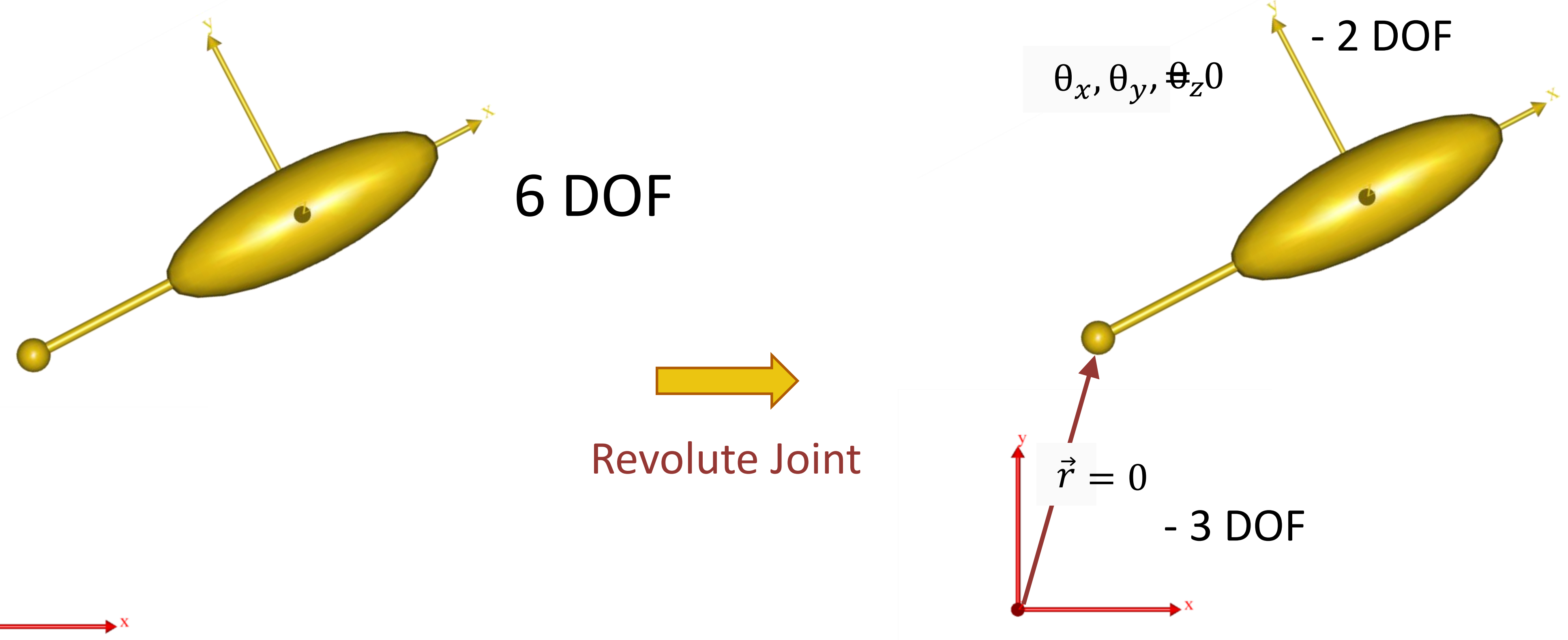
Ground-Segment revolute joint

Revolute joint

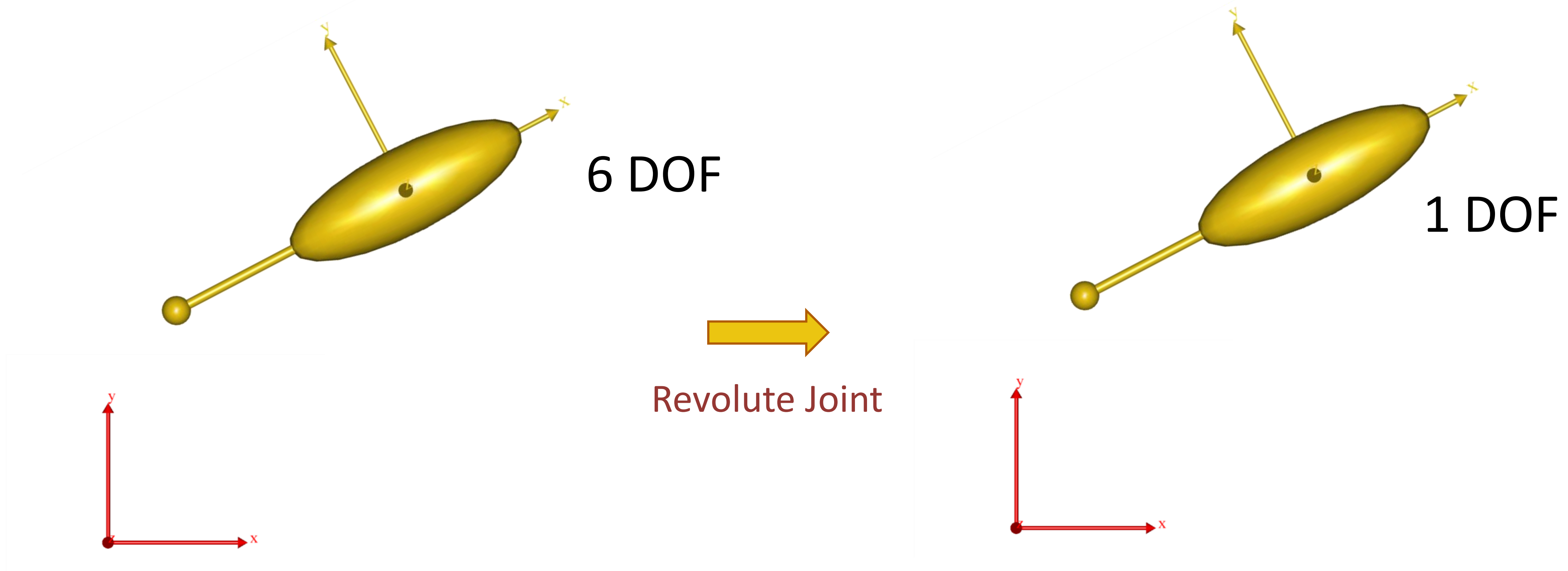


6 DOF

Revolute joint



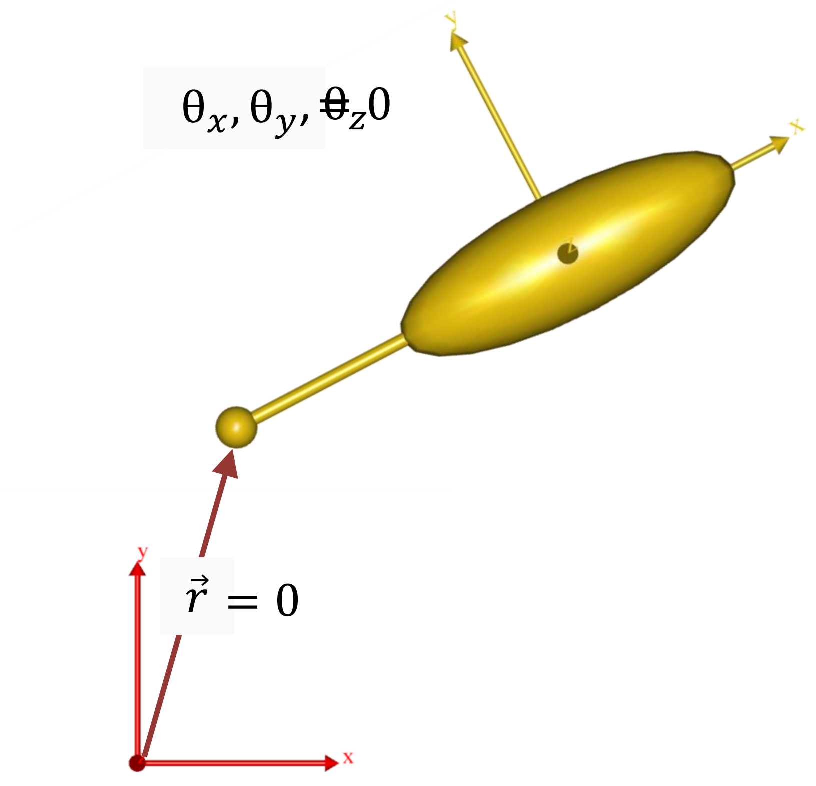
Revolute joint



Measures and drivers

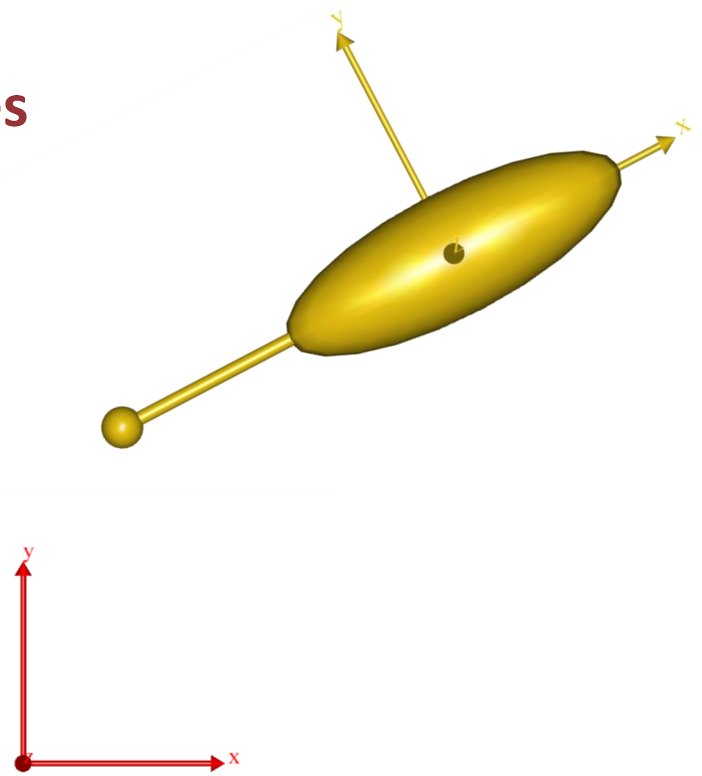
- Creating a revolute joint
  - Step 1: Measure $\vec{r}$ and rotational euler angles
  - Step 2: Constrain $r_x, r_y, r_z, \theta_x, \theta_y = 0$

$$\underbrace{r_x, r_y, r_z, \theta_x, \theta_y}_{-5\ dof}$$



Measures and drivers

- Creating a revolute joint
  - Step 1: Measure $\vec{r}$ and rotational euler angles **Kinematic Measures**
  - Step 2: Constrain $\underbrace{r_x, r_y, r_z, \theta_x, \theta_y}_{-5\,dof} = 0$ **Drivers**



Measures and drivers

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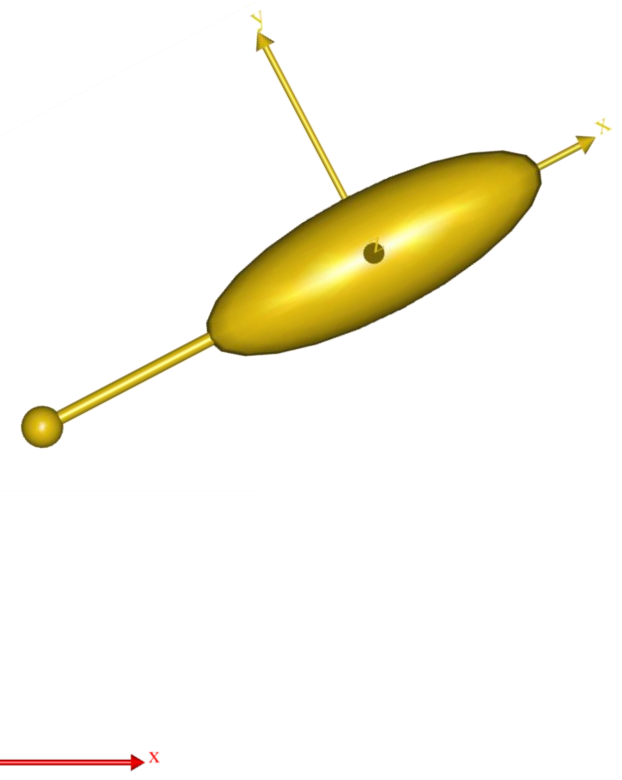
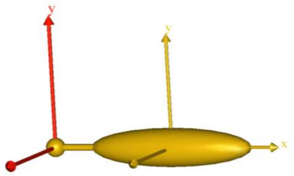


Measures and drivers

- 1 DOF still free
  - Can be used to move the segment
- Driver for the 1 DOF
  - Drivers also enforce time varying constraints

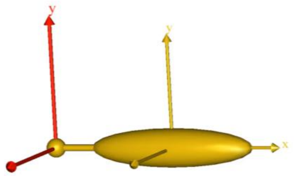


But what is the measure to be driven?

Candidate: Revolute joint angle θ_z (1 DOF)

Human Model

- Hard Drivers
  - Constraints exactly satisfied
- Soft Drivers
  - Constraints satisfied as closely as possible
- Hard Drivers > Soft drivers



Human Model

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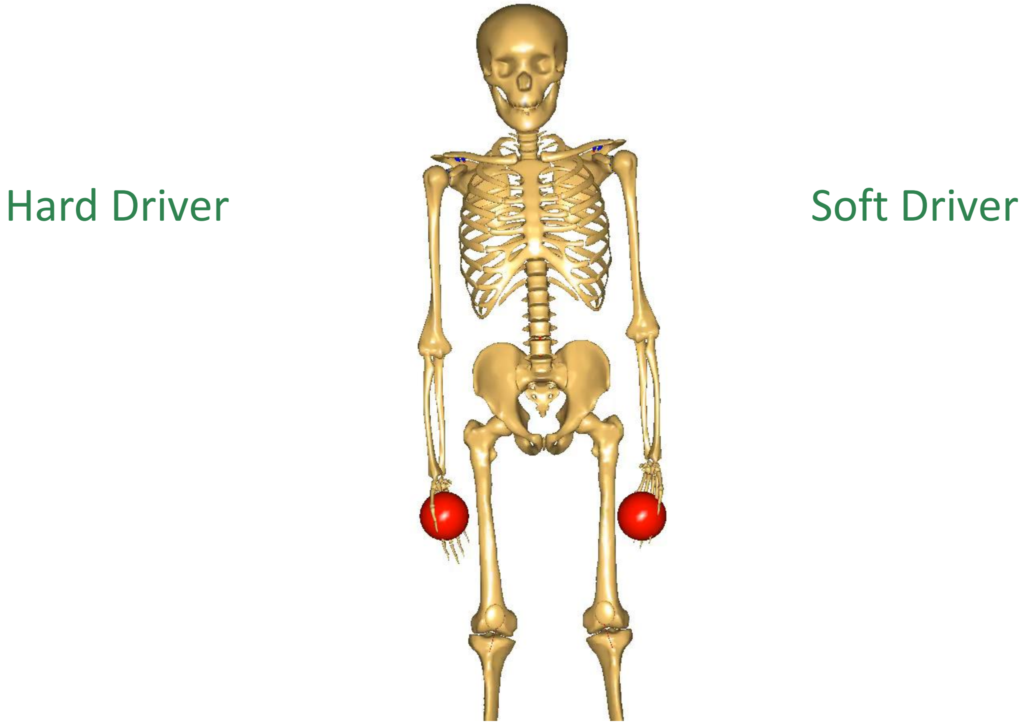
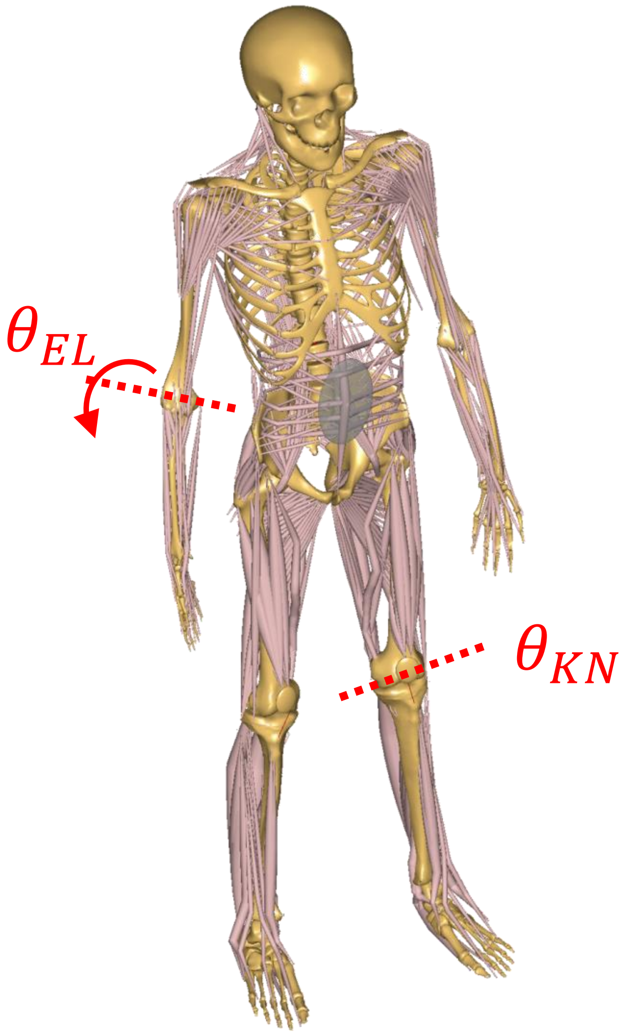
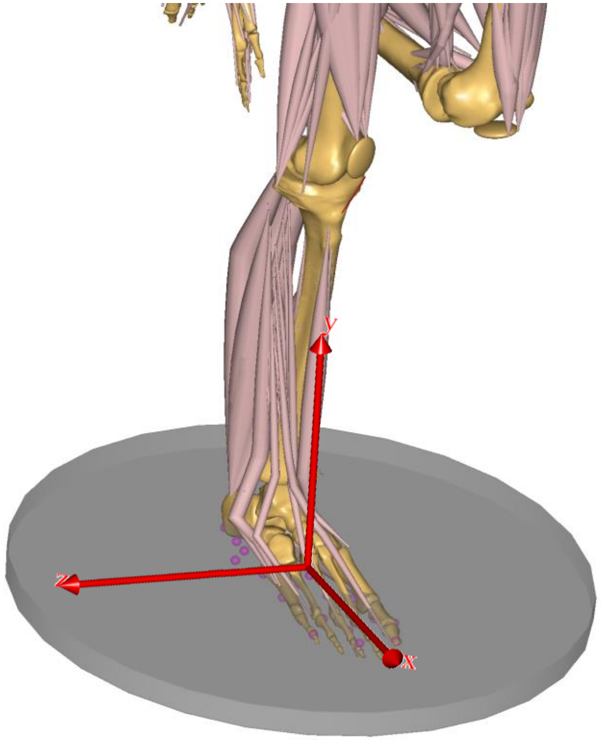


Human Model

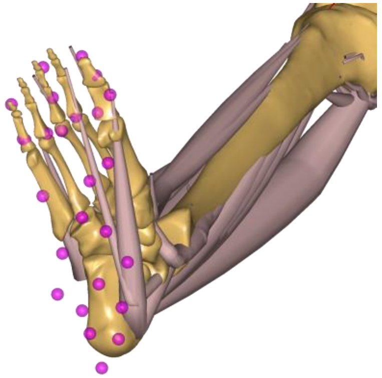


- 44 DOFs
- Manually specify trajectories for all DOFs?
  - Feasible to do in AnyBody
- Soft drivers for 44 Measures (Joint angles)
  - Try to enforce default standing position
- Will be overridden by hard drivers, if any!

Placing Foot on Ground

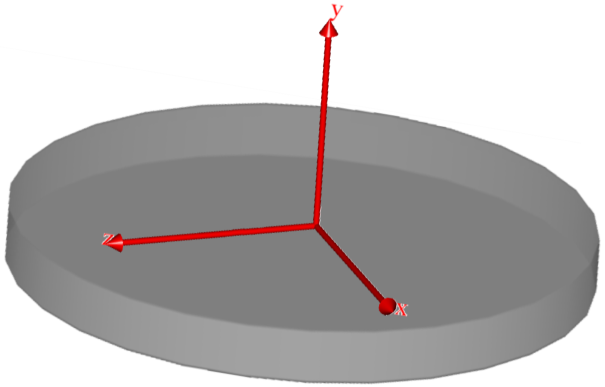


Placing Foot on Ground

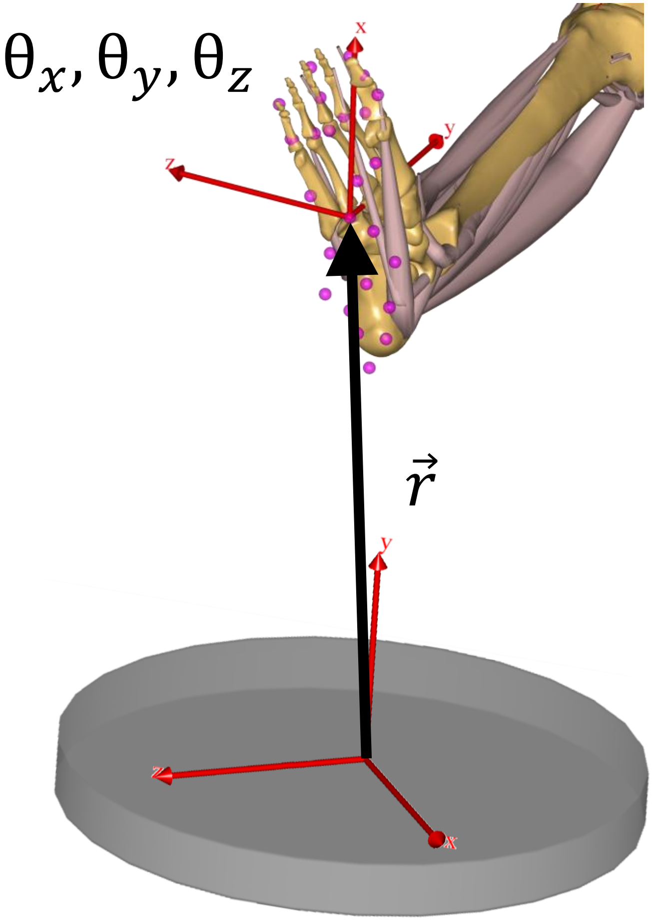


6 independent DOF between foot and force plate

Constrain with measures & drivers

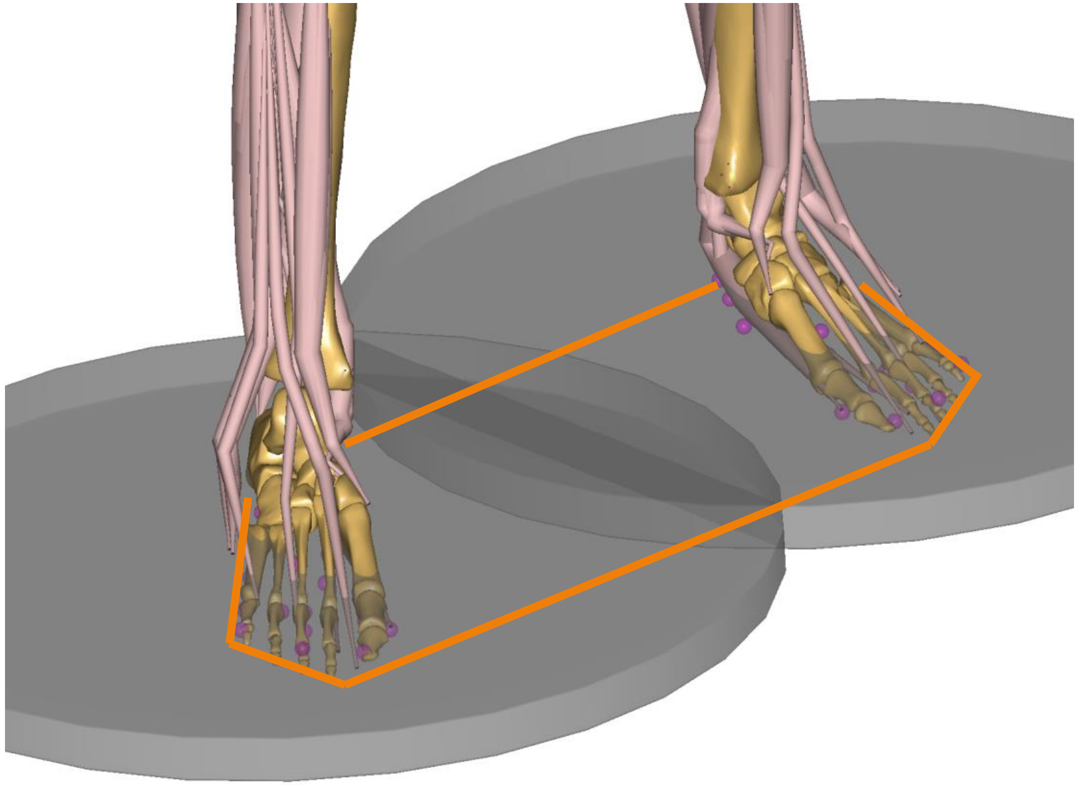


Placing Foot on Ground

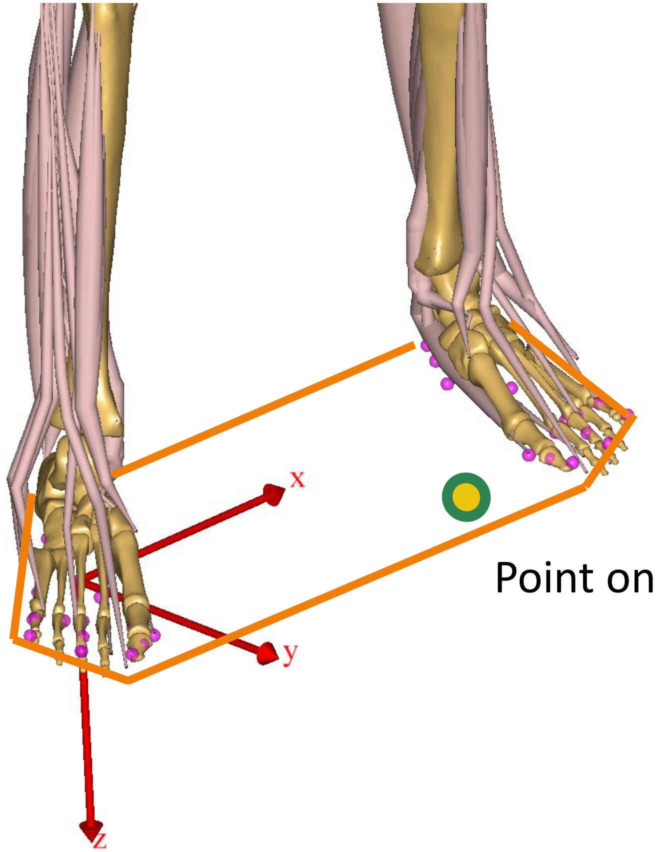


- Constrain translation (Hard drivers)
- Constrain Rotation (Soft drivers)

Balance

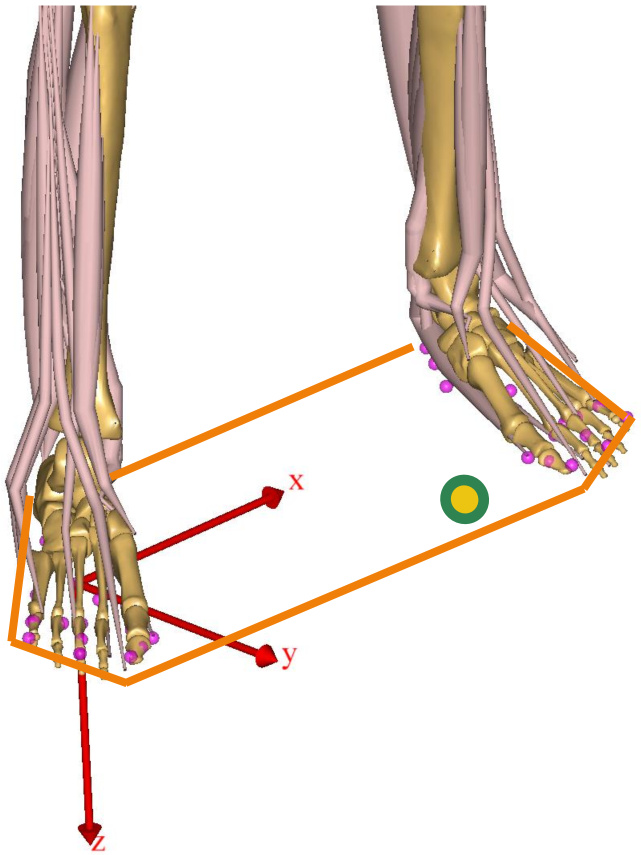


Balance



Point on ground, below CoM

Balance: Measures and Drivers



- Step 1
  - Create measure CoM coordinates in 'Balance Frame'
- Step 2
  - Soft driver on y and x components of measure
  - Drive towards midpoint on x axis

Kinematics

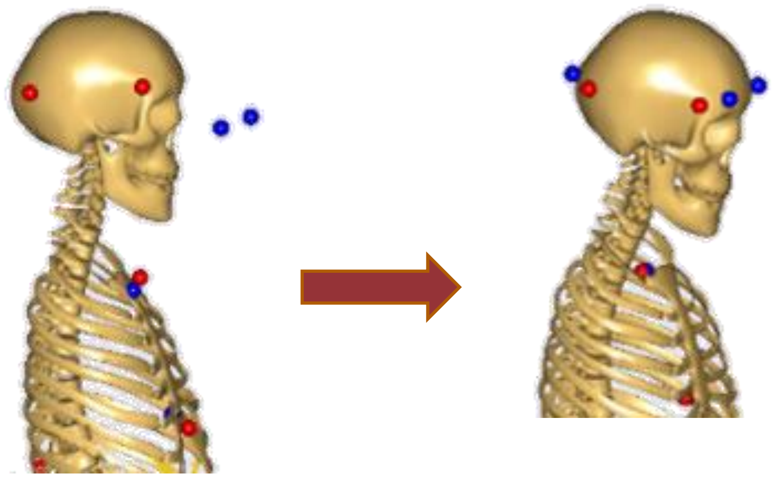
Fully measured
e.g, full MoCap

Partially measured

No exact data, Only task requirements known

Kinematics from MoCap

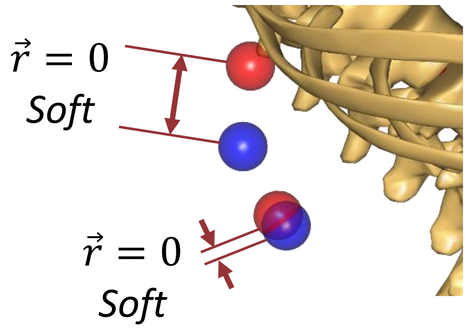
- To mimic MoCap motion in model
  - Model & MoCap markers must match up
  - Throughout motion



- MoCap marker
- Model marker

Kinematics from MoCap

- To mimic MoCap in model
  - Model & MoCap markers must match up
  - Throughout motion

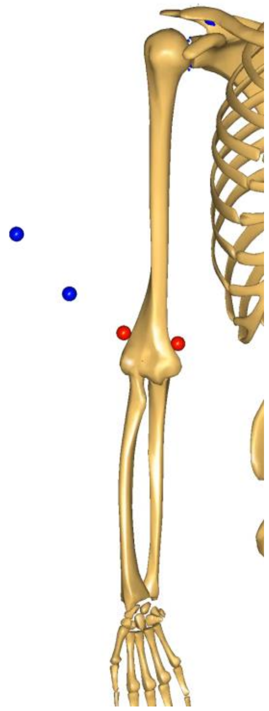


- Solution
  - Kinematic measures calculate marker error
  - Soft drivers on measured error

Kinematics from MoCap

- To mimic MoCap in model
  - Model & MoCap markers must match up
  - Throughout motion

Solving a single time instant

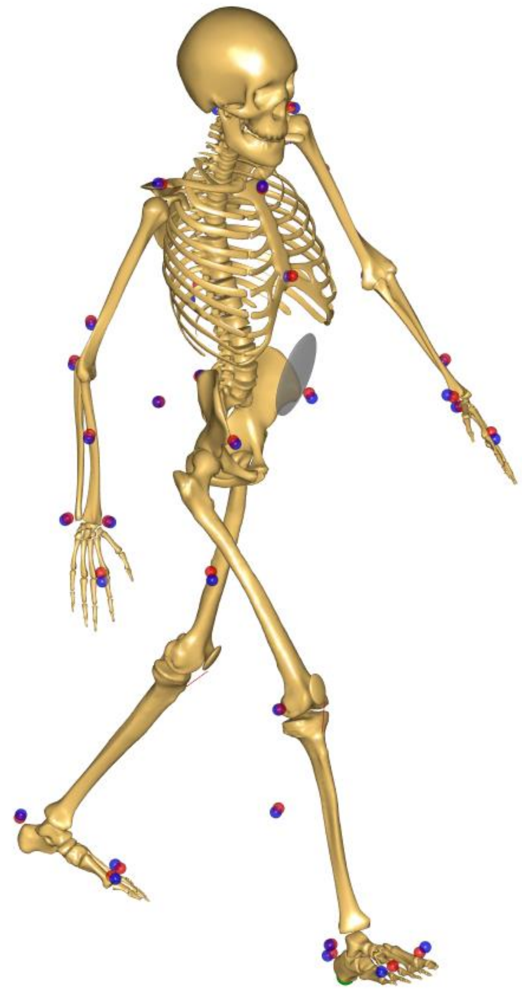


- Solution: Measures and Drivers
  - Kinematic measures of marker error
  - Soft drivers on error

Kinematics from MoCap

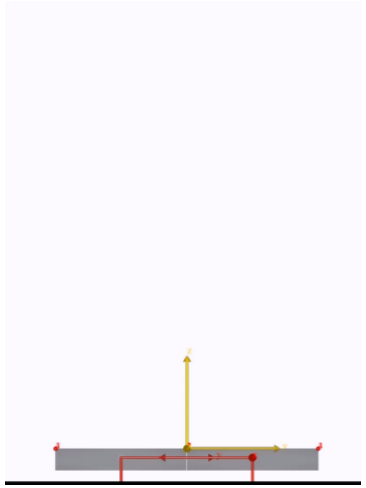
- To mimic MoCap in model
  - Model & MoCap markers must match up
  - Throughout motion

- Solution
  - Kinematic measures of marker error
  - Soft drivers on error
  - Overall marker matchup, as close as possible



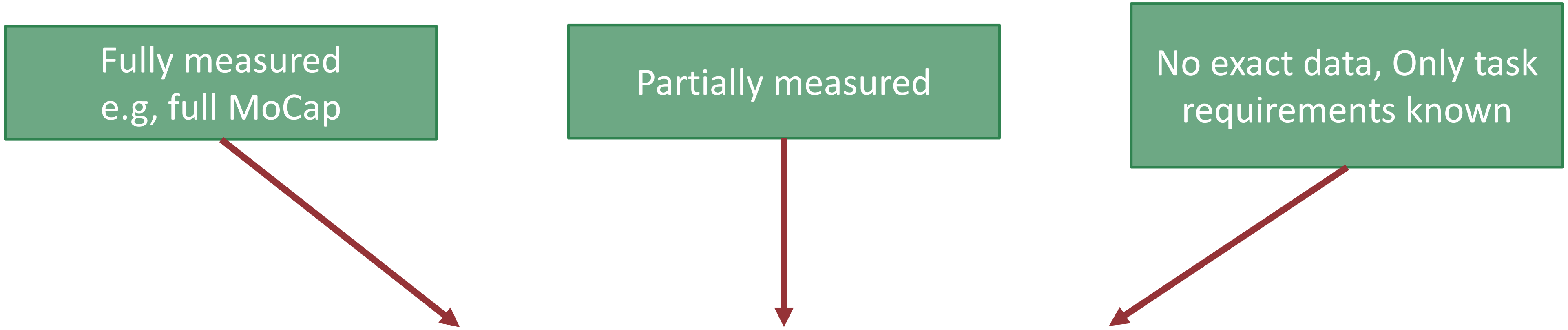
Partially Measured Kinematics

Fully measured e.g, full MoCap → Partially measured ← No exact data, Only task requirements known



- Marker based drivers for lower limb
- CoM Balance drivers for upper limb

Take Home Message



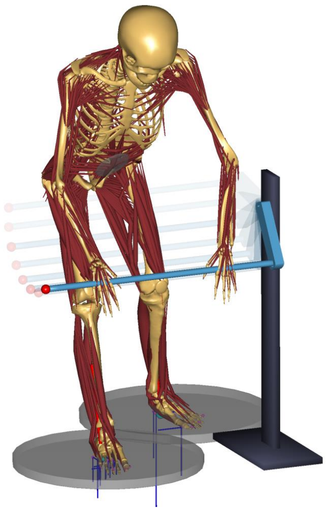
- Underlying modelling concepts
  - Measures and Drivers
- Soft and hard driver constraints can be combined
  - Variety of Complex motions

What can my model tell me?

- Kinematics
  - Joint angles (like in gait analysis)
    - Predict kinematics when full experimental data is unavailable
  - Distances/angles between any two segments
  - Medical measurements
    - E.g., Lordosis, Kyphosis, Pelvic tilt, Pelvic incidence etc.
  - Contact areas and CoP at joints
    - Force dependent kinematics (FDK) algorithm in AnyBody
  - Muscle and ligament lengths

What can my model tell me?

- Kinetics (Forces)
  - Joint moments (like in gait analysis)
  - Predict Ground Reaction Forces + CoP
    - See webcast on AnyBody's GRF prediction algorithms by Dr. Michael Skipper Andersen
  - Muscle and Joint Reaction forces
  - Joint contact pressures
    - Force dependent kinematics (FDK) algorithm in AnyBody



Musculoskeletal Modelling From Scratch

Concepts made easy!

What can software be used for?

ReWalk Eksokeleton,
Argo Medical Technologies

How much external support?

www.commons.wikimedia.org

Design load for daily activities?

pixabay.com

Best design for performance?

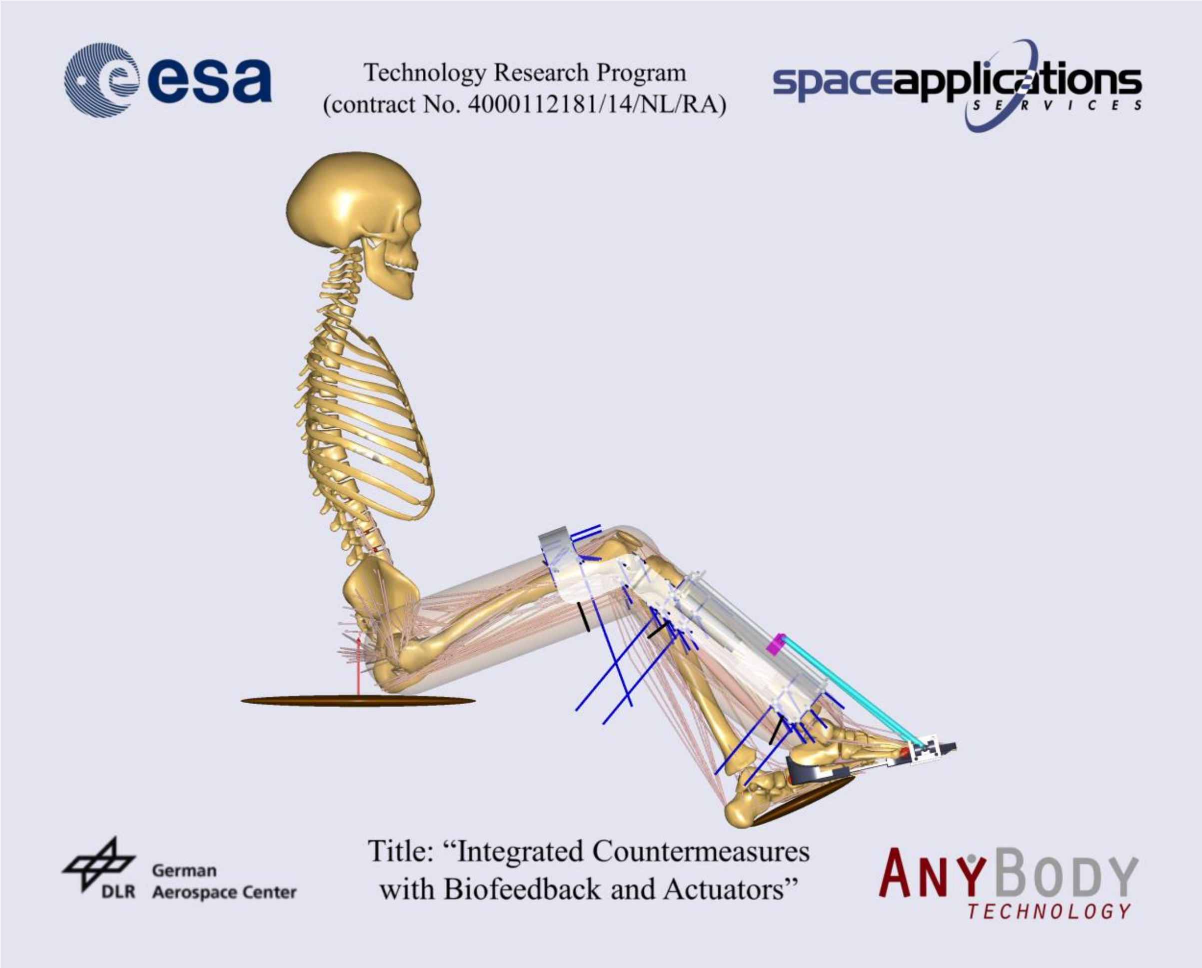
What can software be used for?

Product design:

- Virtual prototype testing
- Functional improvements

Example:

- Training device
- Focus on soleus and gastrocnemius muscles only
- Virtual testing



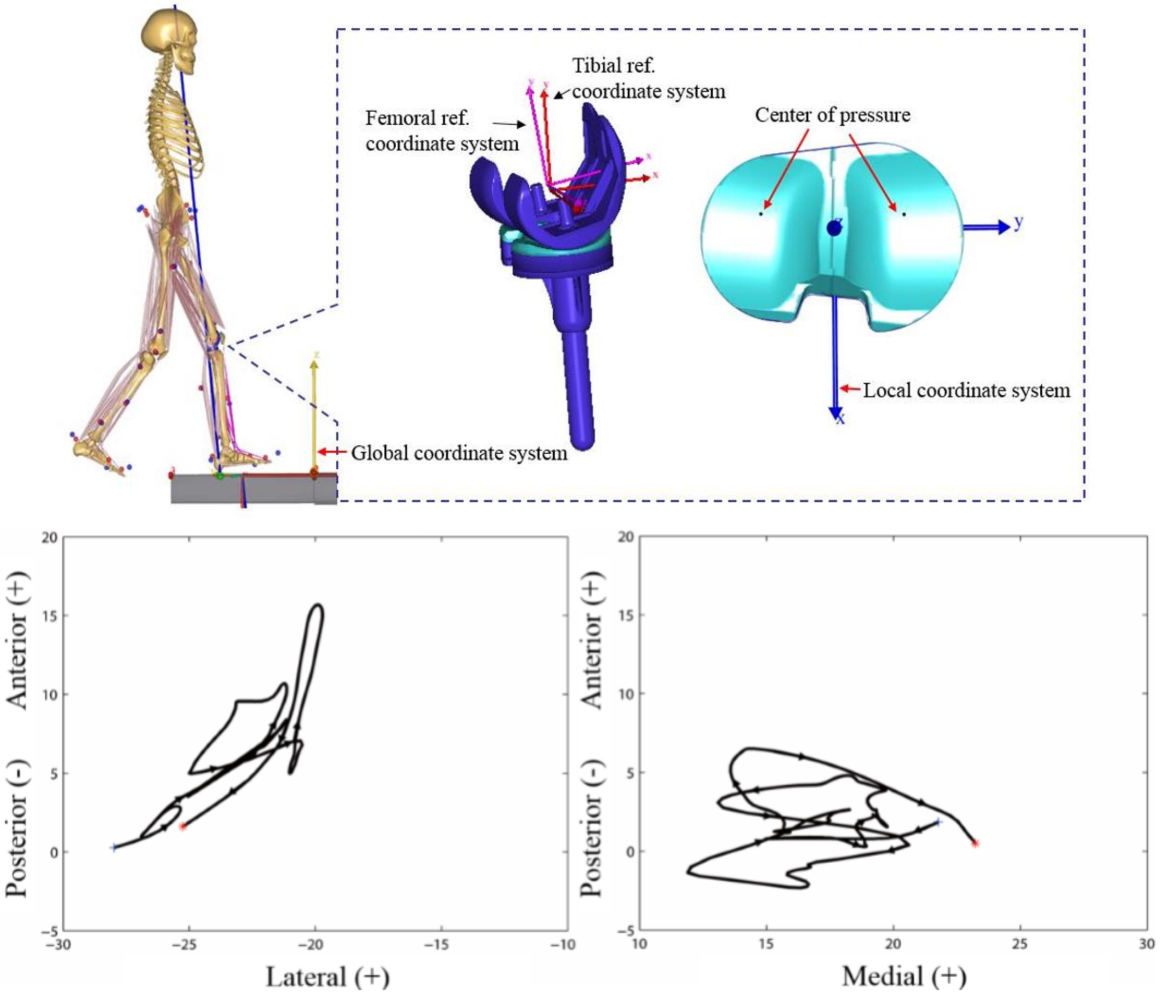
What can software be used for?

Product design:

- Virtual testing
- Data analysis

Example:

- Chen and Jin, J Biosurface and Tribology 2016
- Zimmer NKII during right turn
- Grand Challenge competition to predict in vivo knee loads



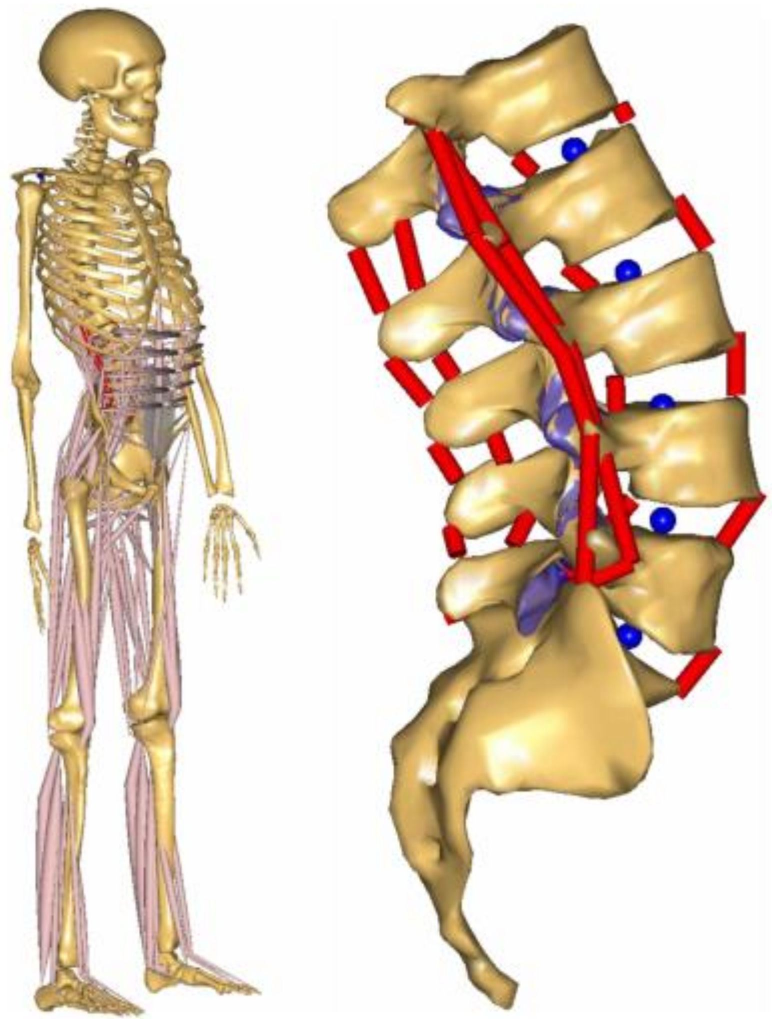
What can software be used for?

Answer research questions:

- Mechanics of body parts
- Understanding function of the human body

Example:

- A numerical study to determine the effect of ligament stiffness on kinematics of the lumbar spine during flexion, Putzer *et al. BMC Musculoskeletal Disorders 2016*
- Ligament function investigations

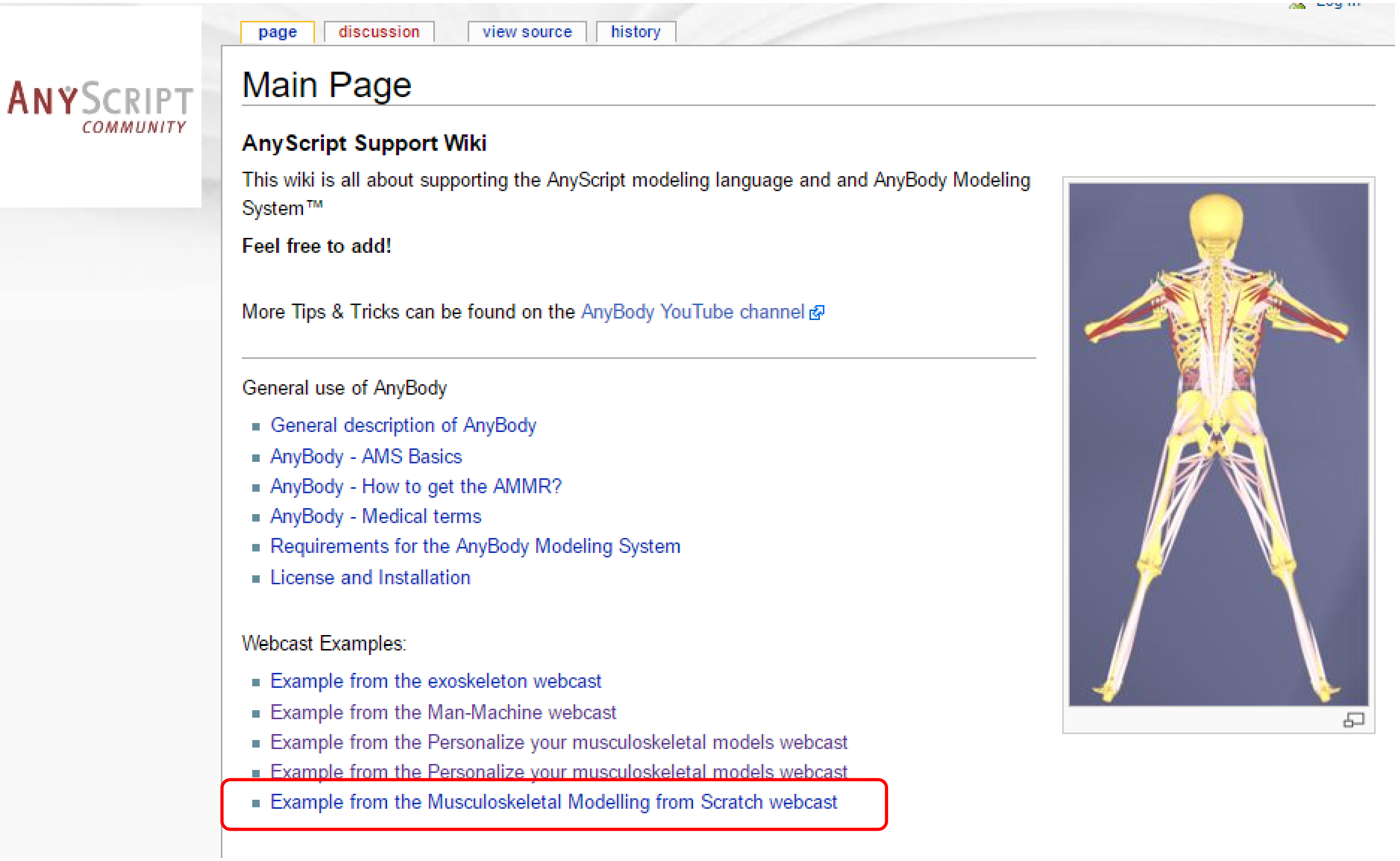


What can software be used for?

And applied in many other fields:

- Orthopedics/Trauma
- Human oriented research
- Automotive industry
- Aerospace industry
- Furniture design
- Sports and sports equipment
- Etc.

wiki.anyscript.com



AnyScript Community

page | discussion | view source | history

Main Page

AnyScript Support Wiki

This wiki is all about supporting the AnyScript modeling language and and AnyBody Modeling System™

Feel free to add!

More Tips & Tricks can be found on the AnyBody YouTube channel

General use of AnyBody

- General description of AnyBody
- AnyBody - AMS Basics
- AnyBody - How to get the AMMR?
- AnyBody - Medical terms
- Requirements for the AnyBody Modeling System
- License and Installation

Webcast Examples:

- Example from the exoskeleton webcast
- Example from the Man-Machine webcast
- Example from the Personalize your musculoskeletal models webcast
- Example from the Personalize your musculoskeletal models webcast
- Example from the Musculoskeletal Modelling from Scratch webcast

www.anybodytech.com

- Events, dates
- Publication list
- Product download
- Contact information
- **Free trial licenses**

Trial Downloads

Evaluation licenses have full functionality, but they are only valid for 30 days for evaluation of the software. After 30 days they will stop working, and you need to contact AnyBody Technology to purchase a license for the system. Prices are available on request.

Please select the desired product:

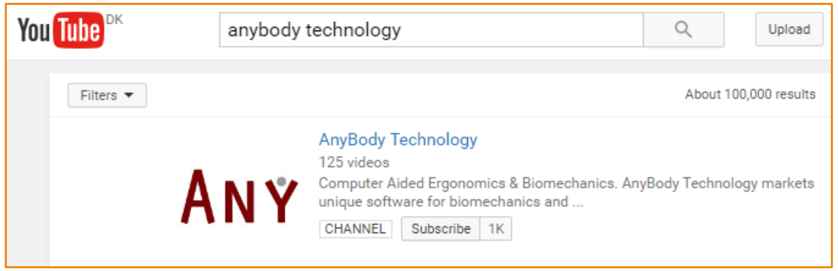
The AnyBody Modeling System™

AnyBody events:

- *22-23 September: The AnyBody Group from Aalborg University at MIMICS 2016*
  Ass. Professor Michael Skipper Andersen will present: “Image-based musculoskeletal modeling”
- *9-14 October: AnyBody presentation and booth at IROS 2016*
  International Conference on Intelligent Robots and Systems in Daejeon, Korea
- *18-21 October: AnyBody presentations at WeRob and ICNR 2016*
  International Symposium on Wearable Robotics in Segovia, Spain

YouTube channel: *anybodytech*

- Previous webcasts, help, demos, tips & tricks



Time for questions: