

# Simulations in Human Movement

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# Motivation

- Study of human movement (ACL rupture)

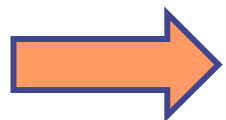


**Skiing**  
(Senner 1998)

- Optimisation of sport activities



**Rowing**  
(Grund 2004)

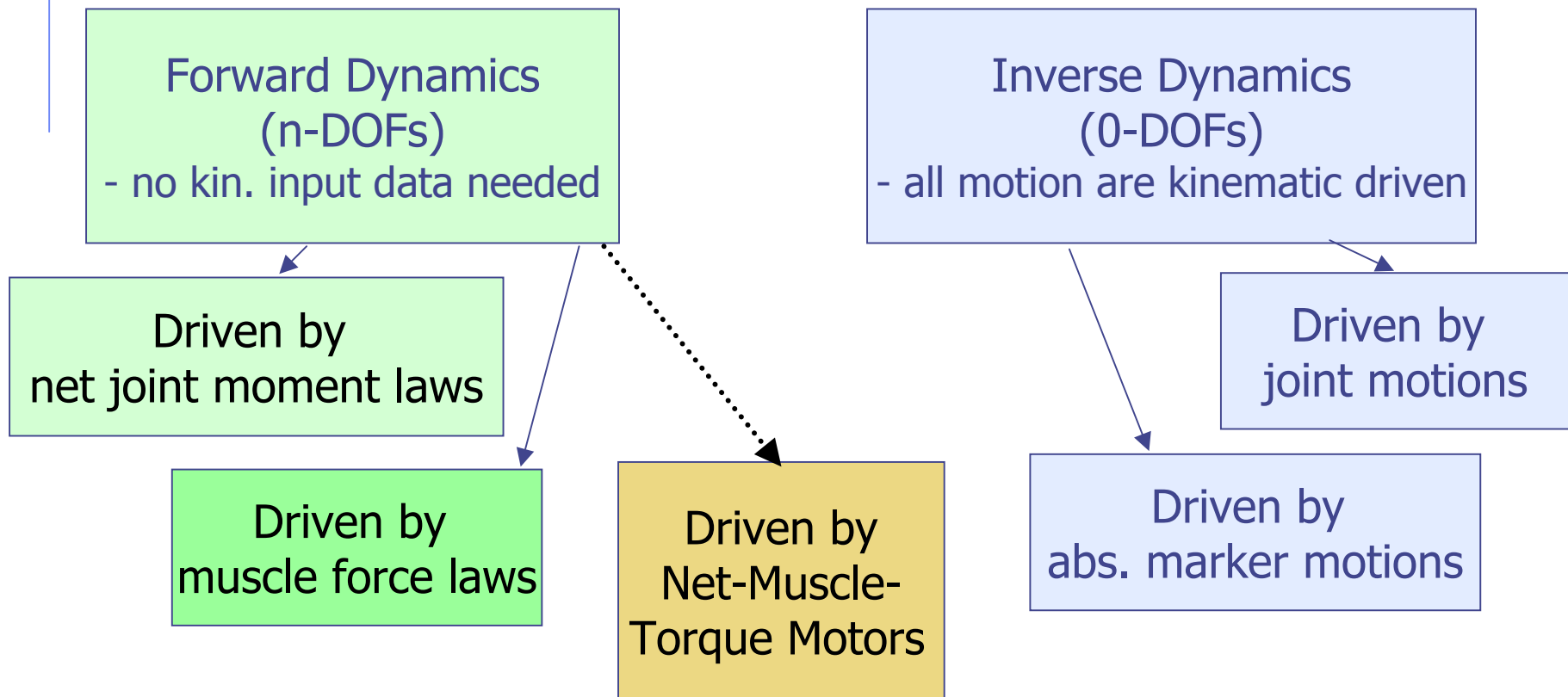
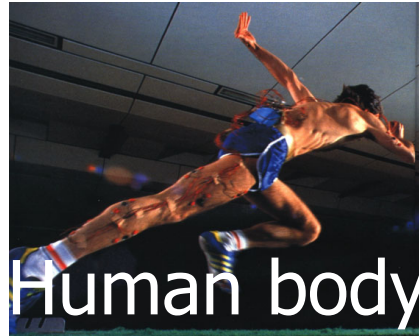


Generation of human body models

# Contents

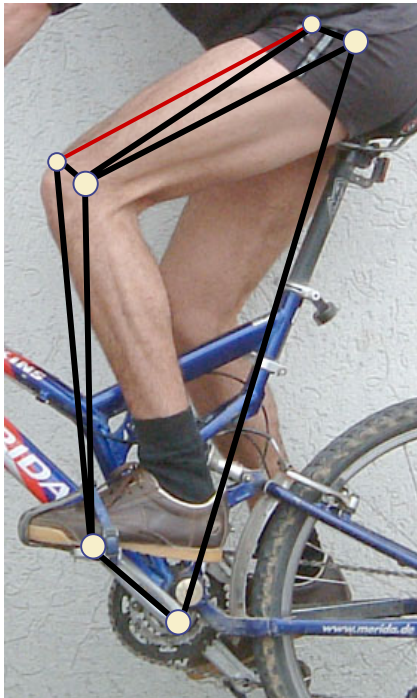
- Simulation techniques of the human body
- Models used for forward dynamics
  - example cyclist
- Models used for inverse dynamics
  - example rowing machine
- Rowing model using the Net-Muscle-Torque Motor
- Summary

# Simulation techniques of the human body



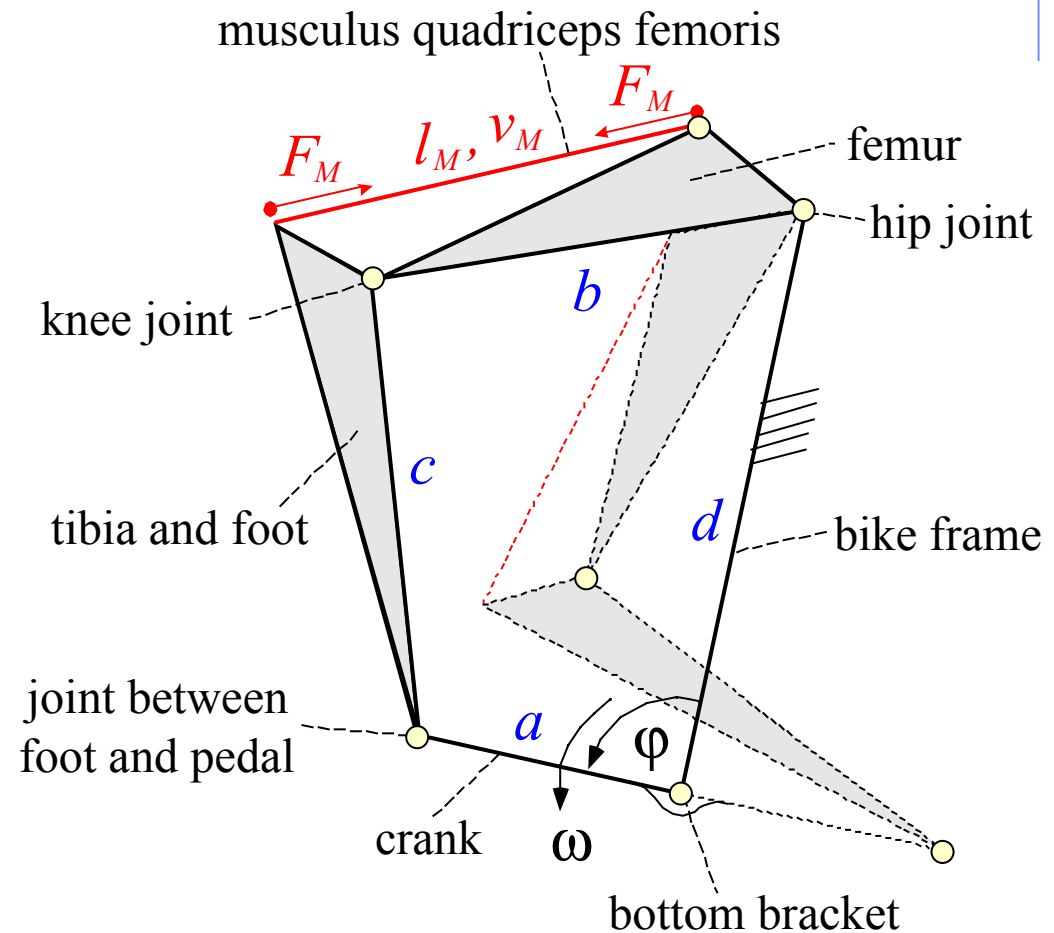
# Forward dynamics - muscle force driven

## Example cyclist



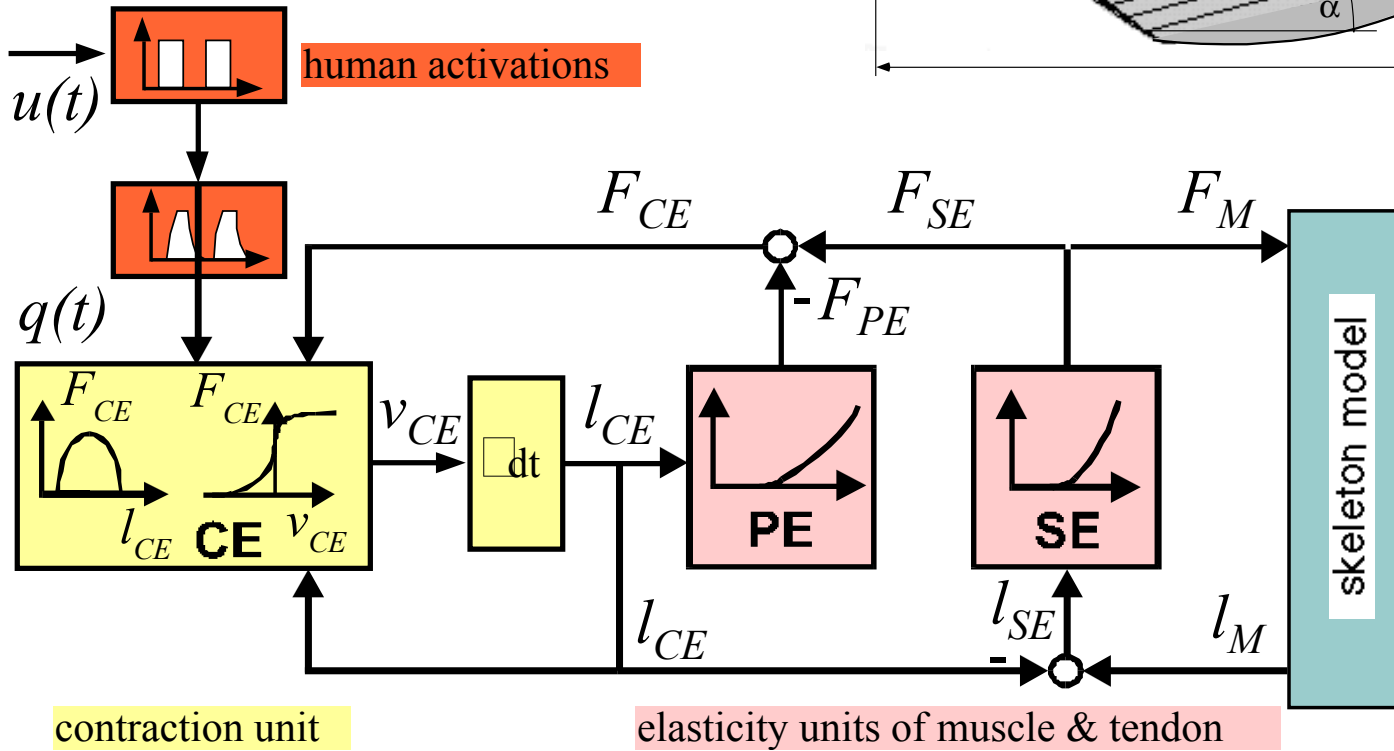
Mechanism: two 4-bar chains

(Jüptner, 2001)



# Model of muscle

(Kryszohn, 1999)



**Muscle force**

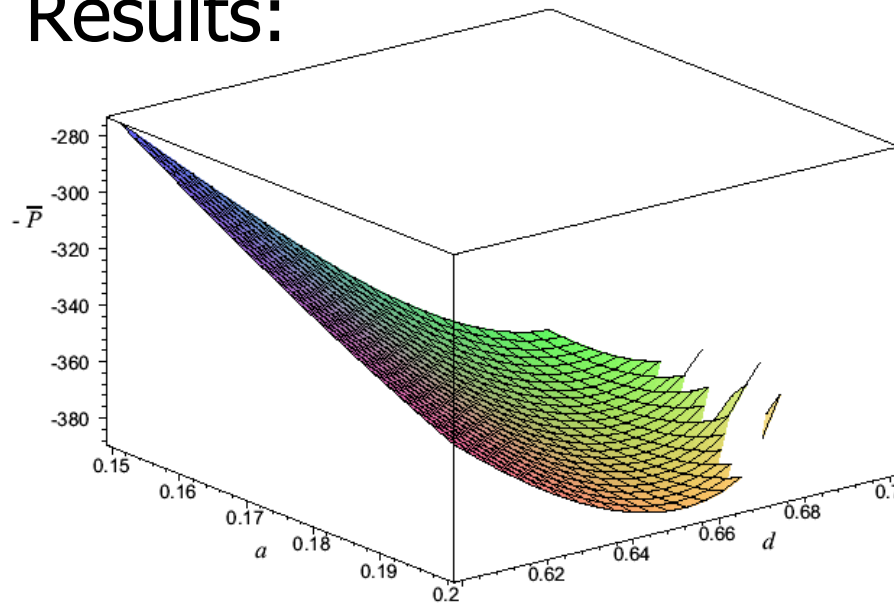
$$F_M = F_M(l_{CE}, v_{CE}, u, t)$$

for  $u = 1, \quad t = \frac{\varphi}{\omega};$

$$\Rightarrow F_M = F_M(l_M, v_M, \varphi_{act}, \varphi_{deact})$$

# Forward dynamics - muscle force driven

## Results:

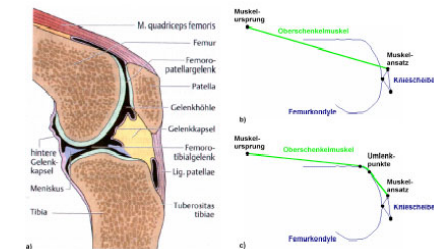


Zur Anzeige wird der QuickTime™  
Dekompressor "Video"  
benötigt.

(Jüptner, 2001, Ertl 2003)

## Problems:

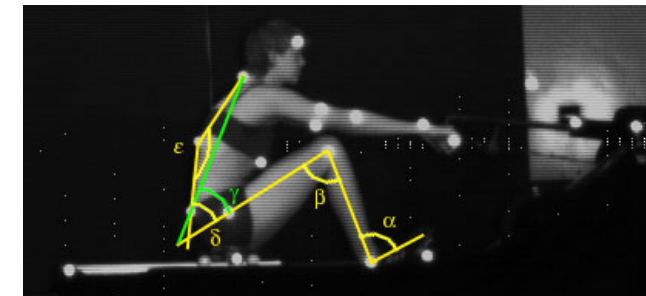
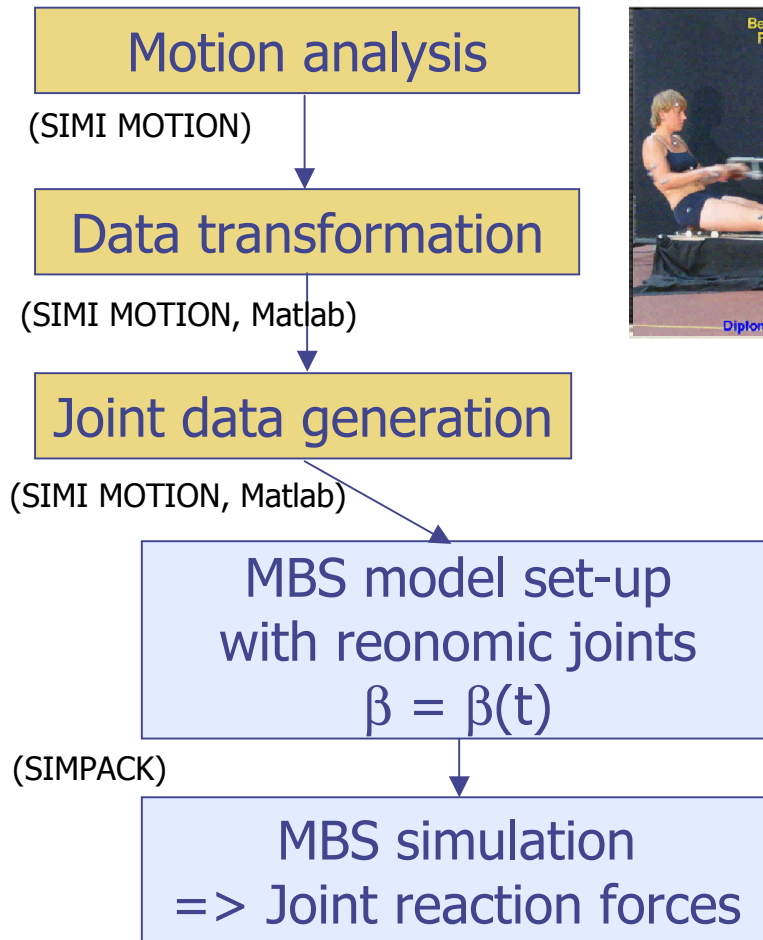
- **Data preparation:**
  - muscle parameters
  - muscle activation behaviour
- **Muscle modelling**
  - multi-attachment points
  - bend around a corner of a body



# Inverse dynamics - joint driven

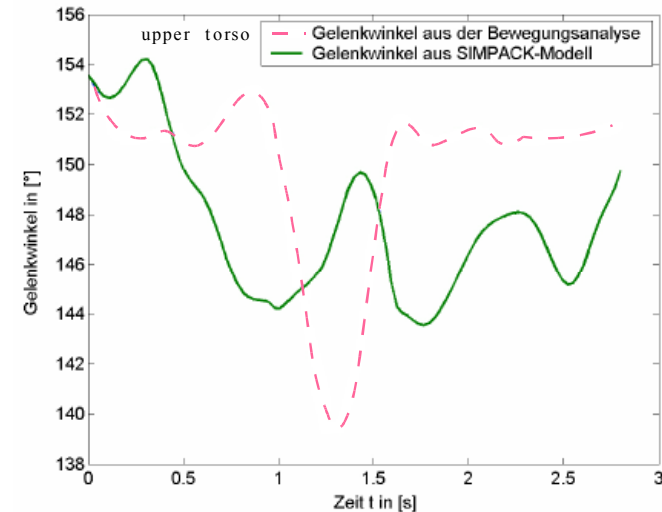
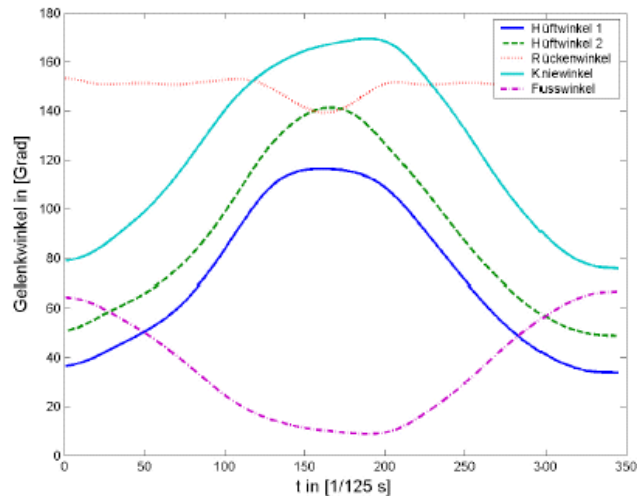
## Standard process for model set-up

(Grund 2004)



# Inverse dynamics - joint driven

## Results for rowing model:



## Problems:

- data have to be filtered and improved by hand.
- exact joint data are not derived from motion analysis.
- simplified MBS-model does not reach all max. joint-angles measured in motion analysis.
- deviations between measured movement and MBS-model cause invalid joint-moments.

# Inverse dynamics - marker driven (Böhm)

## Set-up the model

Marker coordinates from motion analysis  
 $x(t), y(t), z(t)$

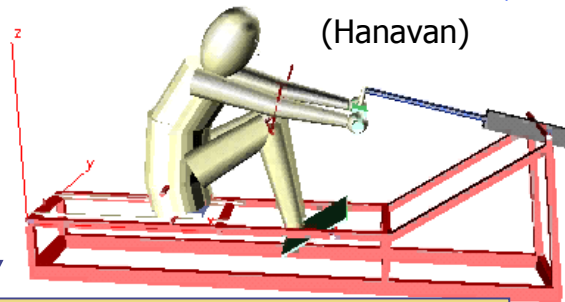


Tension- marker bodies are driven by 3D marker coordinates

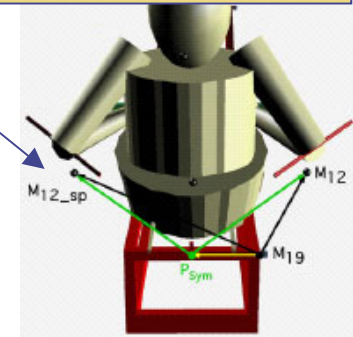
MBS movement due to marker motion

MBS simulation  
 => joint motion, joint reaction forces

MBS model of the human body on rowing machine (7 DOFs)

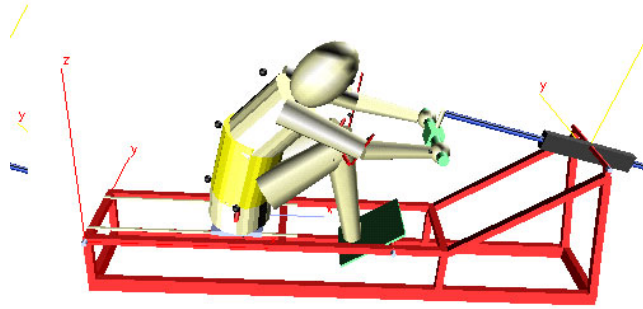


Tension-marker bodies are added in the model attached by spring elem. on the human body model

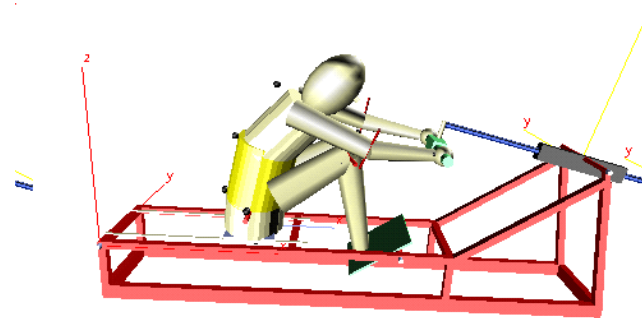


# Inverse dynamics - marker driven

## Results for rowing model:



Spring stiffness value  $10^2$



Spring stiffness value  $10^7$

## Problems:

- Adjusting of the spring-damper element
- Correct initial state of the model

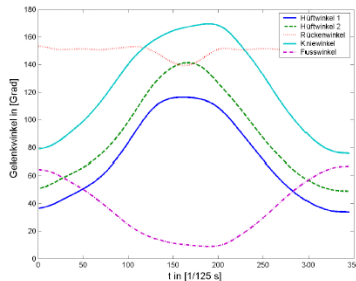
## Benefit:

- Realistic and joint conform body motions
- Model exports correct joint angles w.r.t. time

# Rowing model using Net-Muscle-Torque Motor (NMTMs)

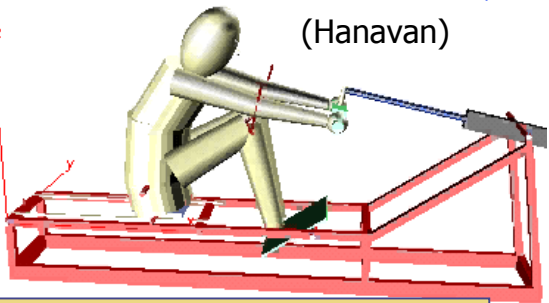
## Set-up the model

Joint motion from  
 - motion analysis  
 -MBS simul. (tension markers)



Net Muscle-Torques are given by a control law satisfying joint motion

MBS model of the human body on rowing machine (7 DOFs)



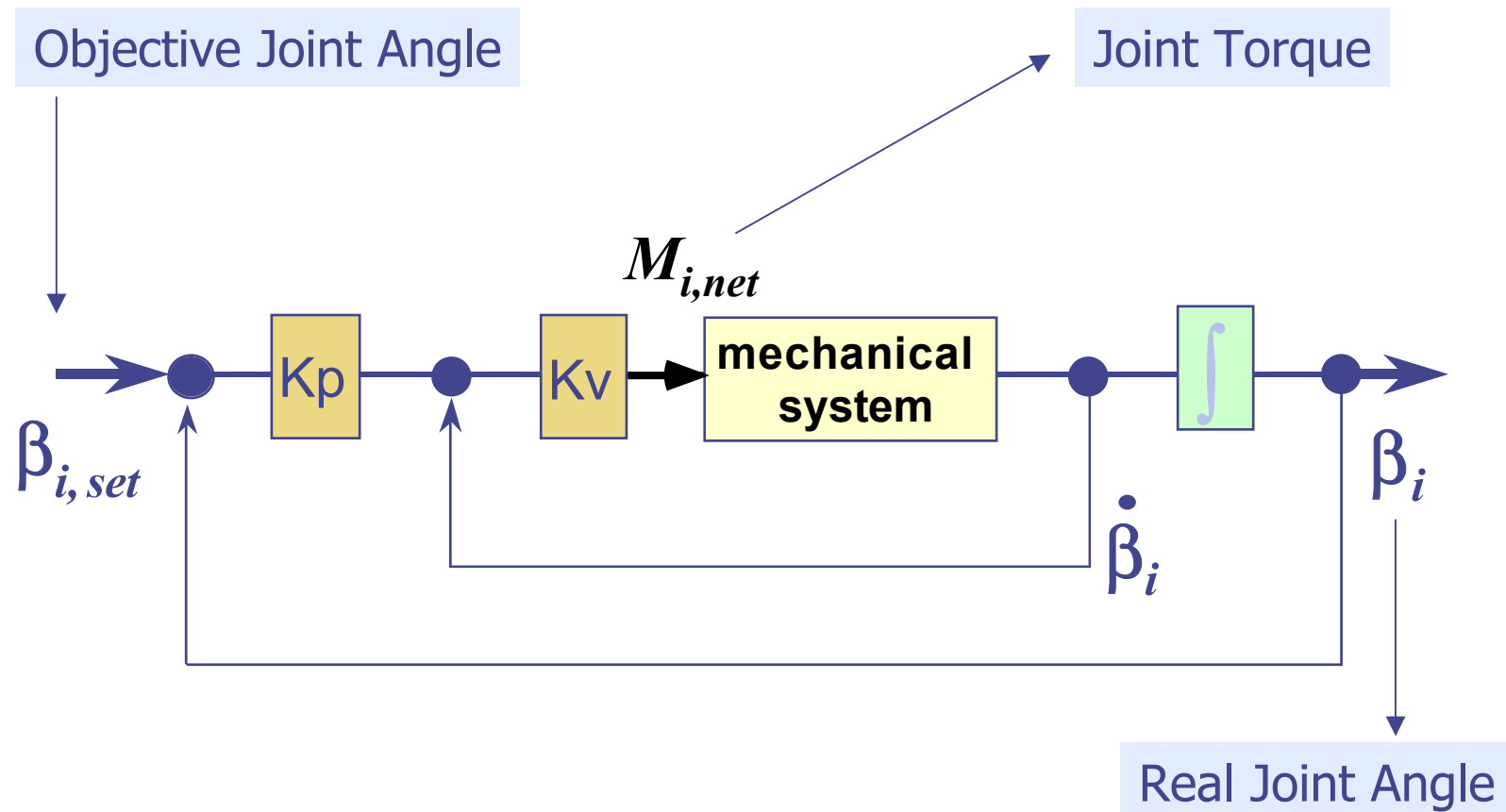
All DOFs are forced by a Net-Muscle-Torque Motor

MBS movement due to NMTMs

MBS simulation  
 => body motion, applied joint torques

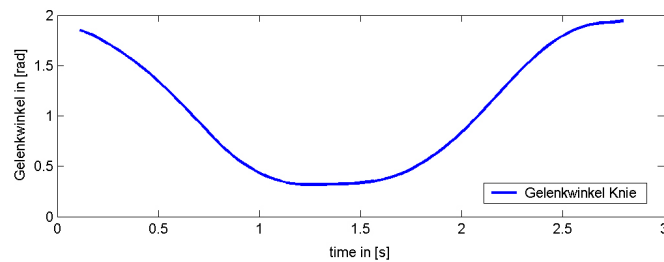
# Control law of the Net Muscle-Torque Motor

(Wallrapp 1998)

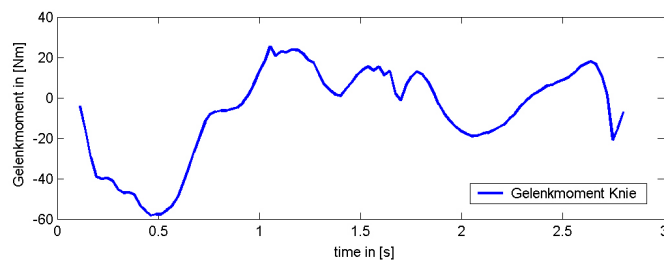


# Rowing model using Net Muscle-Torque Motors (NMTMs)

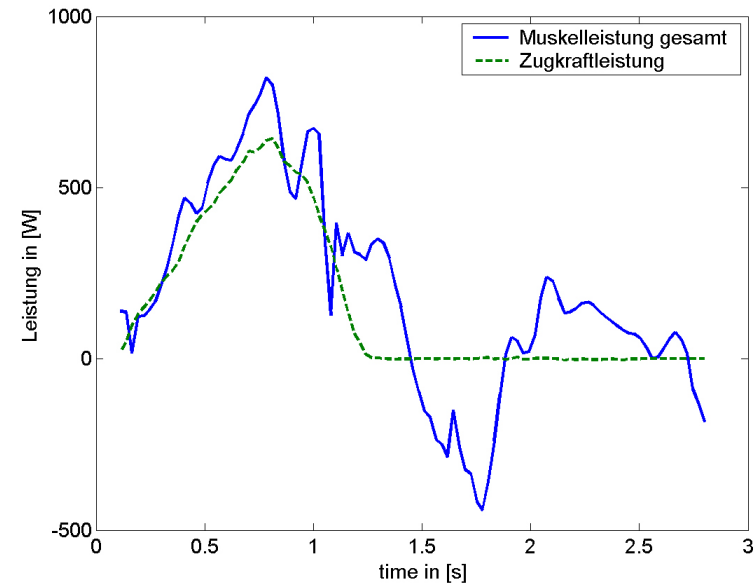
## Results:



knee joint angle



knee joint torque



- muscle power
- power of rowing machine

## Problems:

- Control parameter, rough motion of torque,

## Benefit:

- Realistic body motions, results of applied net joint torques
- Objective values of joint forces and net muscle power

# Summary

- 1 Input functions of joint or marker motions given from a motion analysis drive the 3D human body model
- 2 Realistic body motions, joint torques and muscle power are results of simulations when the Net-Muscle-Torque Motor is introduced
- 3 For simple 2D models muscle force laws are useable
- 4 SIMPACK is an efficient tool to simulate human body motions

## **Open problems in SIMPACK modelling**

- 1 Efficient force elements with multi-attachment points and which can bend around a body corner
- 2 Efficient 3D body contact model for human body segments

Thank you for your attention!

