Simulations in Human Movement

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Motivation

- Study of human movement (ACL rupture)

Skiing
(Senner 1998)

- Optimisation of sport activities

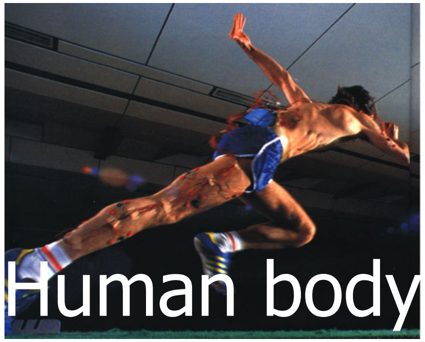
Rowing
(Grund 2004)

→ 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
(n-DOFs)
- no kin. input data needed

Inverse Dynamics
(0-DOFs)
- all motion are kinematic driven

Driven by
net joint moment laws

Driven by
muscle force laws

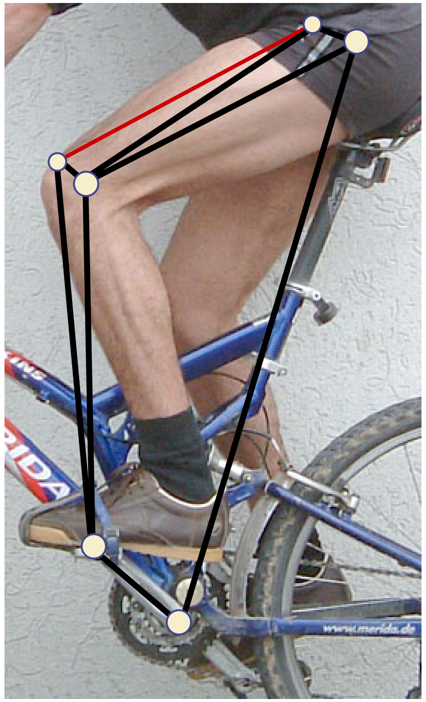
Driven by
Net-Muscle-
Torque Motors

Driven by
joint motions

Driven by
abs. marker motions

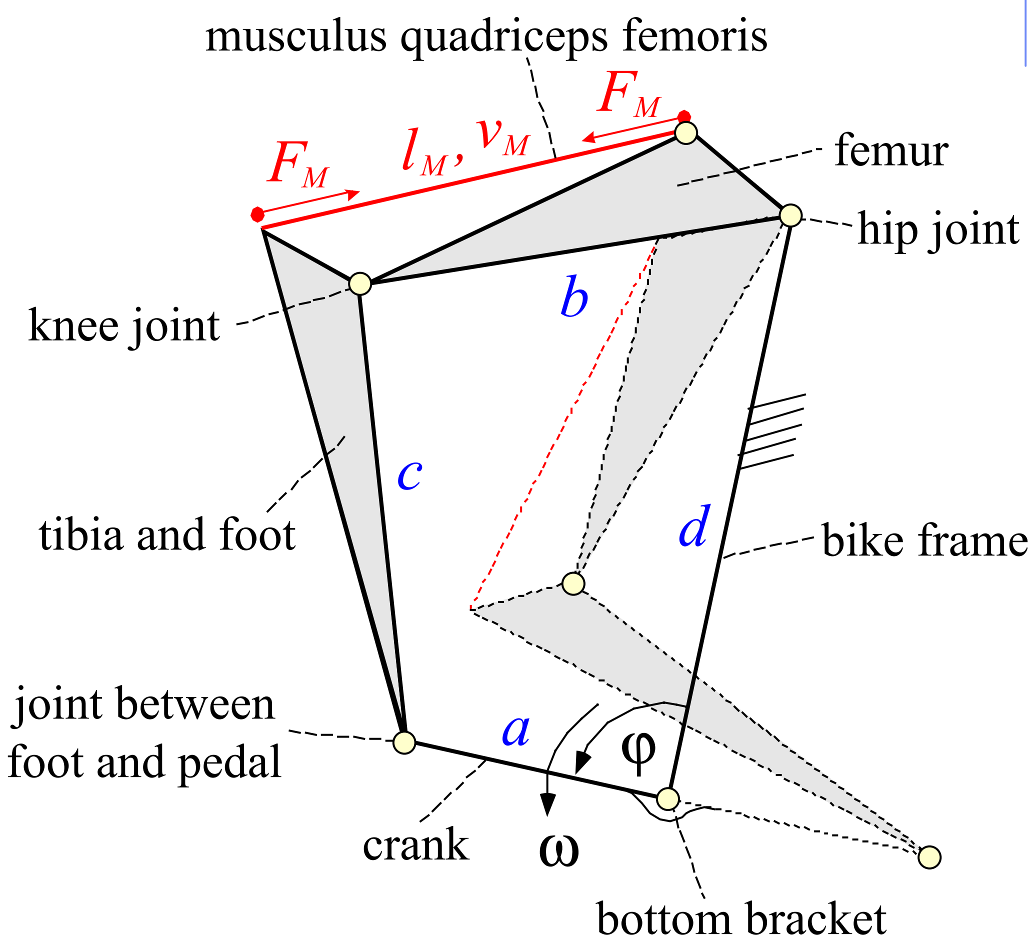
Forward dynamics - muscle force driven

Example cyclist

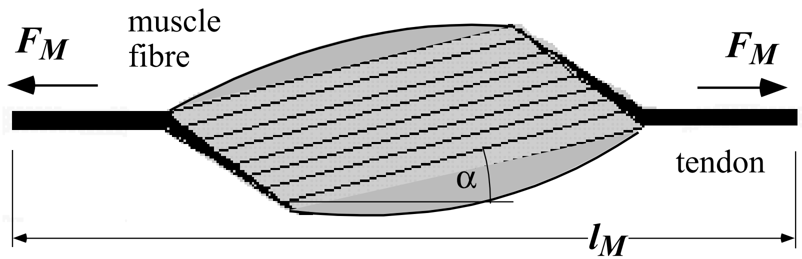


Mechanism: two 4-bar chains

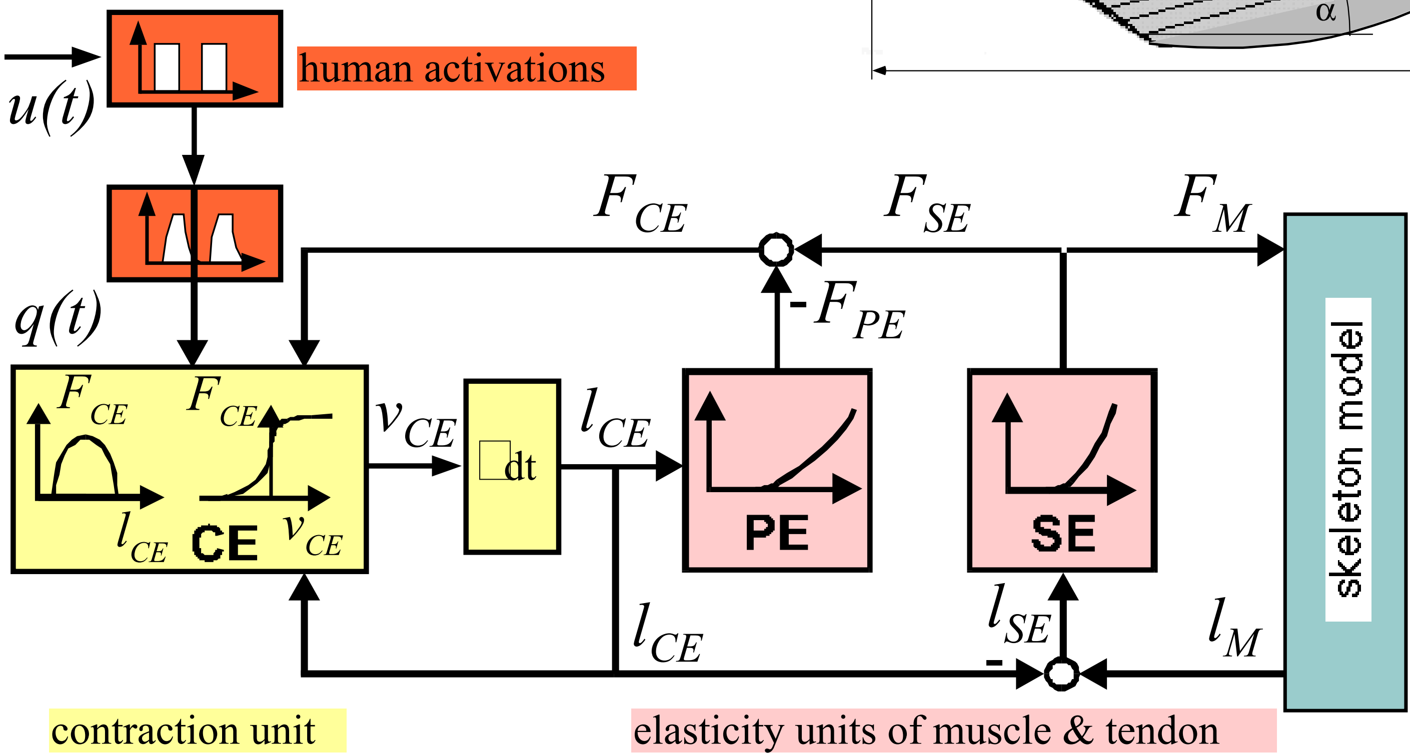
(Jüptner, 2001)



Model of muscle



(Kryszohn, 1999)



Muscle force

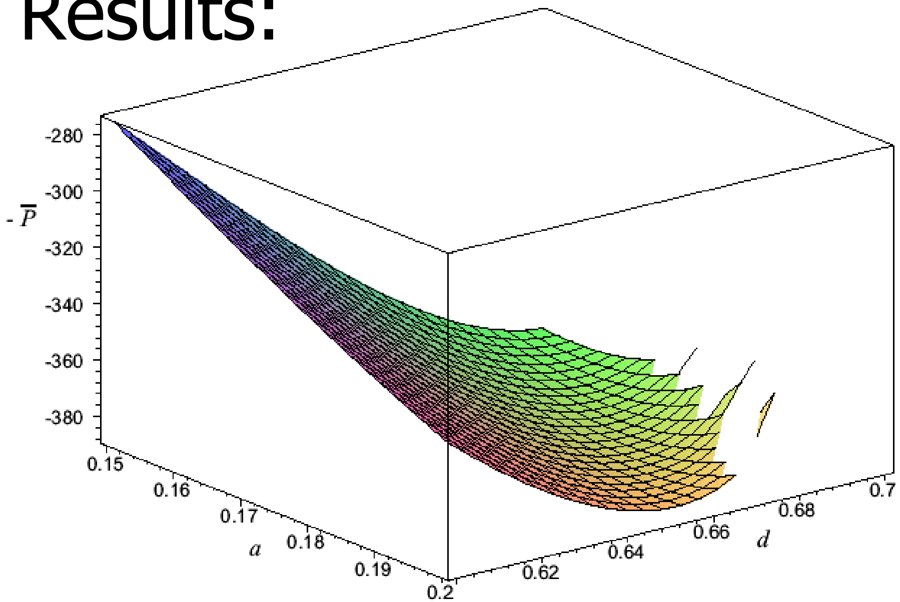
$$F_M = F_M(l_{CE}, v_{CE}, u, t)$$

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

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

Forward dynamics - muscle force driven

Results:

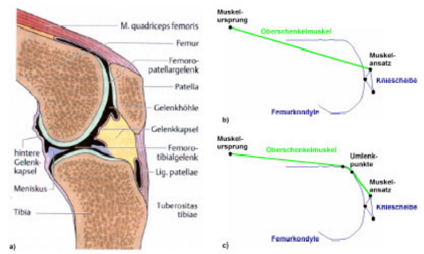


Zur Anzeige wird der QuickTime™ Dekompressor "Video" benötigt.

(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)

Motion analysis

(SIMI MOTION)

↓

Data transformation

(SIMI MOTION, Matlab)

↓

Joint data generation

(SIMI MOTION, Matlab)

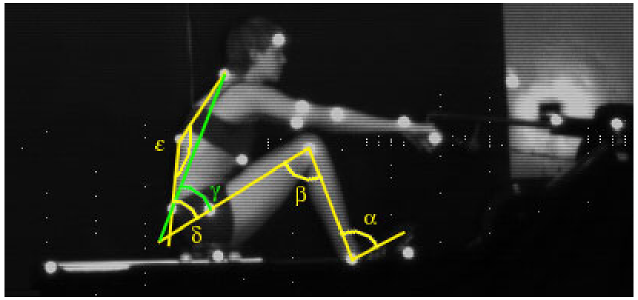
↓

MBS model set-up
with reonomic joints
$\beta = \beta(t)$

(SIMPACK)

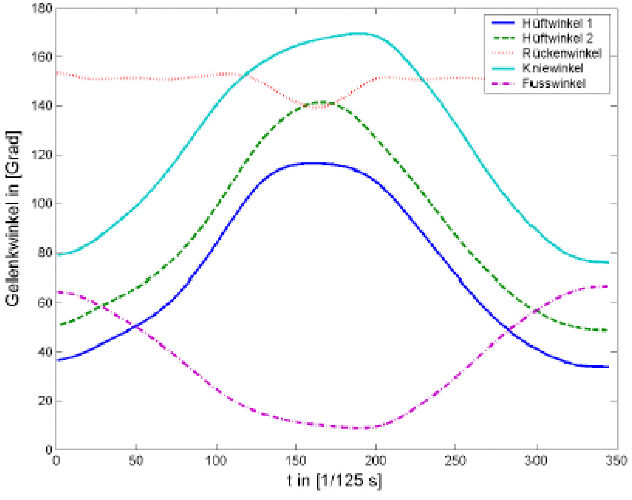
↓

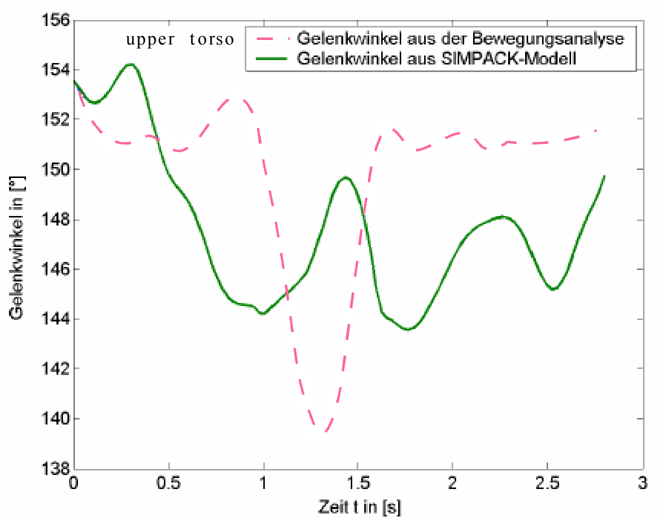
MBS simulation
=> Joint reaction forces



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.

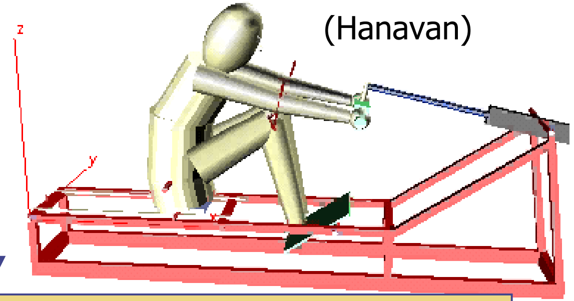
Inverse dynamics - marker driven (Böhm)

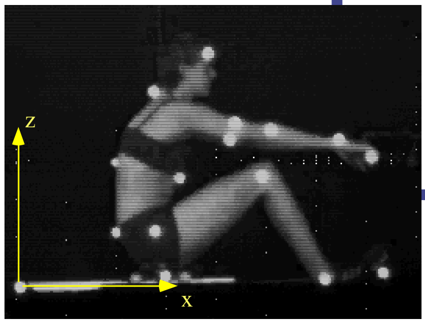
Set-up the model

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

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

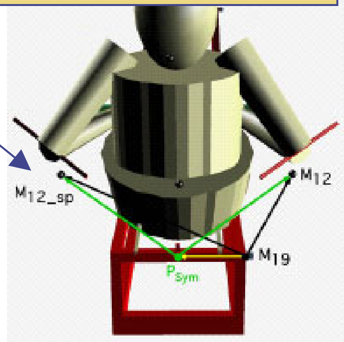
(Hanavan)





Tension- marker bodies are driven by 3D marker coordinates

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

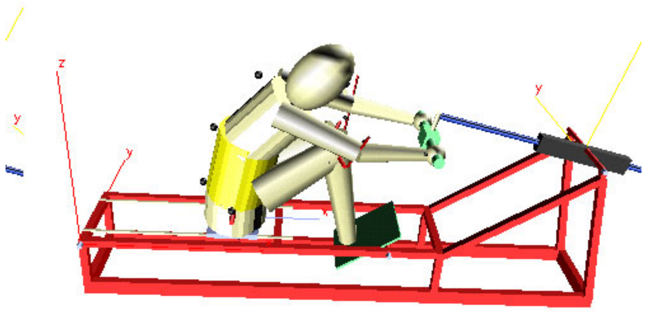


MBS movement due to marker motion

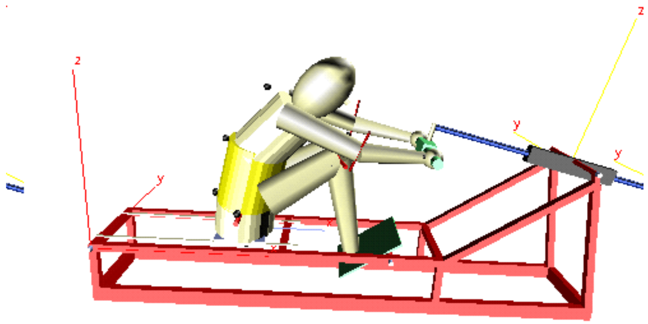
MBS simulation
=> joint motion, joint reaction forces

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

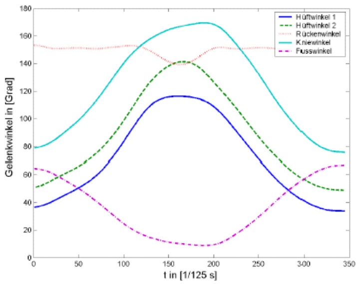
Benefit:

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

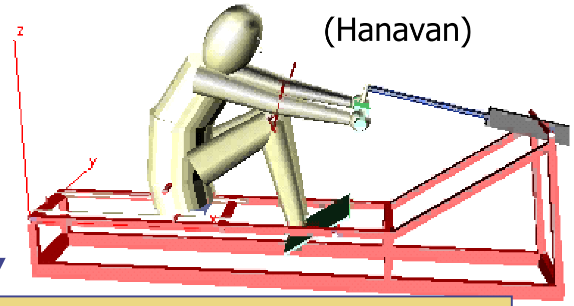
Rowing model using Net-Muscle-Torque Motor (NMTMs)

Set-up the model

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



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



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

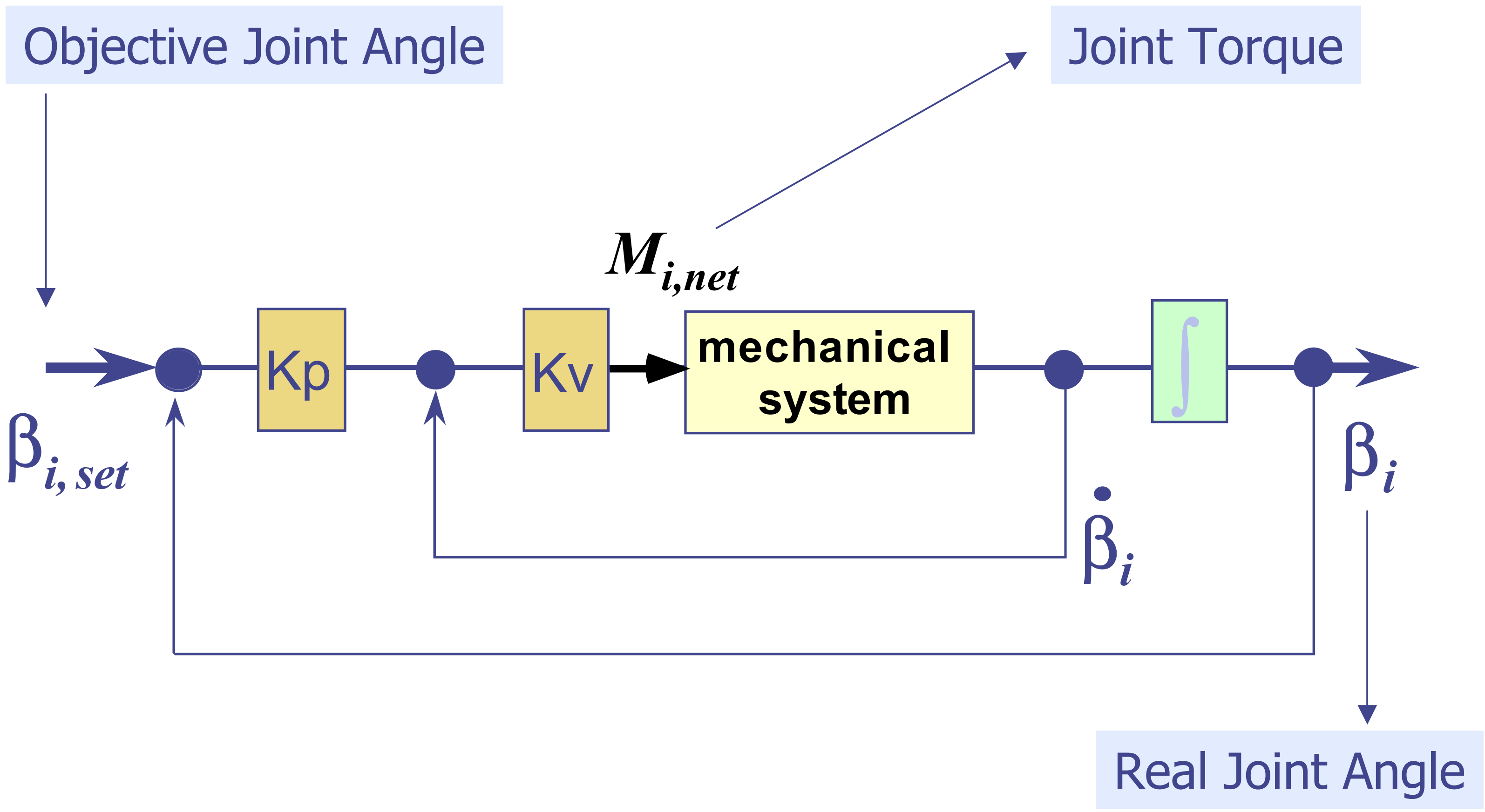
Net Muscle-Torques are given by a control law satisfying joint motion

MBS movement due to NMTMs

MBS simulation
=> body motion, applied joint torques

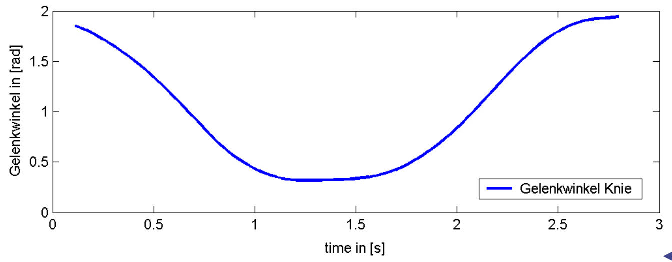
Control law of the Net Muscle-Torque Motor

(Wallrapp 1998)

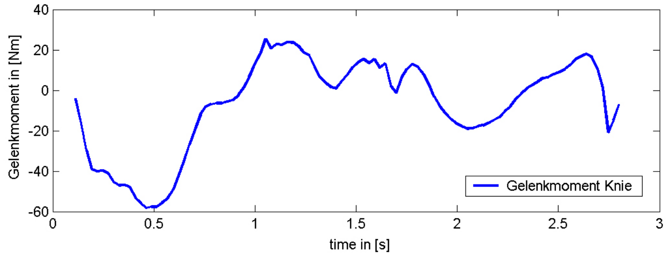


Rowing model using Net Muscle-Torque Motors (NMTMs)

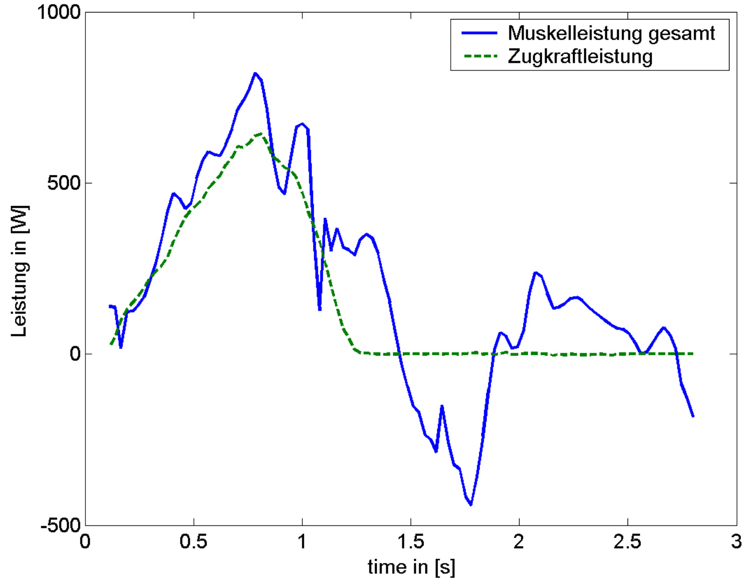
Results:



knee joint angle



knee joint torque



- mucle 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 efficent tool to simulate human body motions

Open problems in SIMPACK modelling

1 Efficent force elements with multi-attachment points and which can bend around a body corner

2 Efficent 3D body contact model for human body segments

Thank you for your attention!