

3M Seminar

Modellbildung und Simulation biomechanischer Systeme

Modeling and simulation of biomechanical systems

Simulation

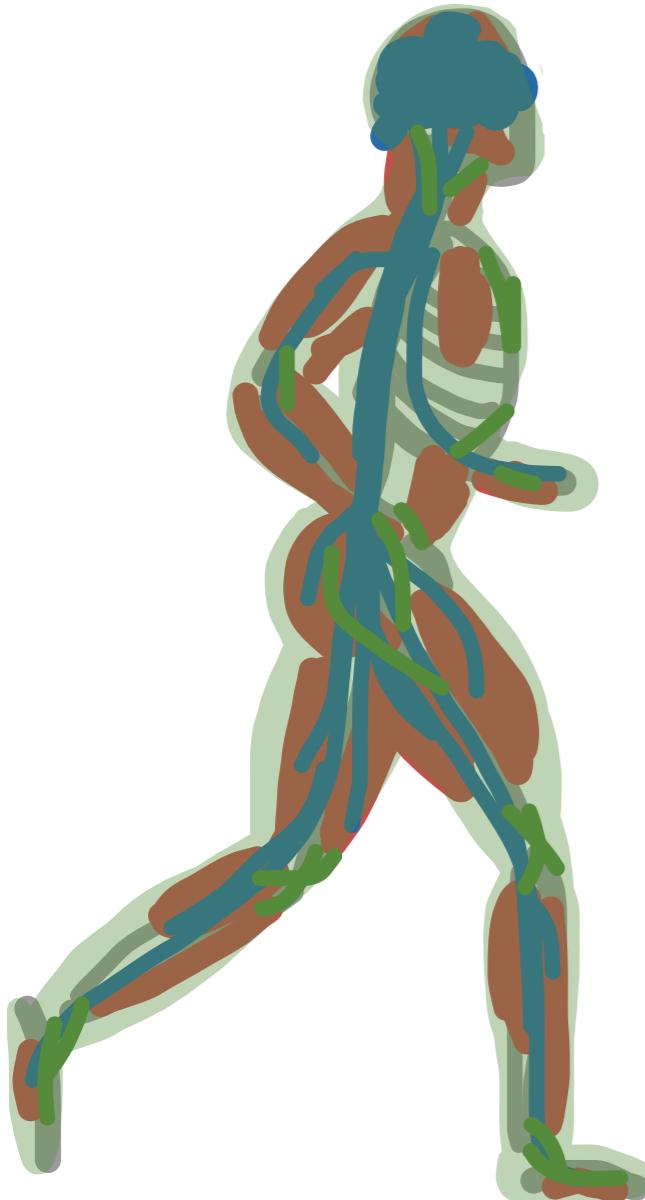
VDI-Richtlinie 3633:

„Simulation ist das Nachbilden eines Systems mit seinen dynamischen Prozessen in einem experimentierfähigen Modell, um zu Erkenntnissen zu gelangen, die auf die Wirklichkeit übertragbar sind.“

„Simulation is: to recreate a system with its dynamic processes in a model which allows to perform experiments with the goal to get insights which are transferable to reality“

Modellbildung und Simulation dynamischer Systeme
Scherf 2012, Oldenbourg

Analysis of human movement



Non-linear system

Many state variables

$$\dot{x}_1 = f_1(x_1, \dots, x_n)$$

⋮

$$\dot{x}_n = f_n(x_1, \dots, x_n)$$

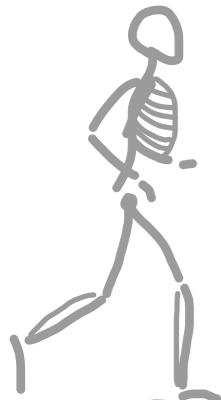
Consider physical laws

- Conservation laws, e.g. energy, momentum
- Kirchhoff law for meshes
- d'Alambert's principle
- Lagrange equations of the second kind

Simplifications and assumptions

- Rigid bodies
- point mass instead of distributed mass
- mass-free force elements (spring)
- ideal joints

Structures and their models



Bones
Structure

Rigid
bodies

$$\frac{d}{dt} \frac{\partial L}{\partial \dot{x}_i} - \frac{\partial L}{\partial x_i} = X_i$$



Ligaments,
cartilage, fat
Springs

Passive
force

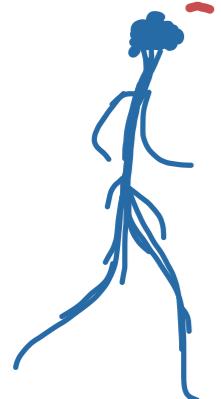
$$F = f(x, \dot{x})$$



Muscles
Motors

Active
force

$$F = f(x, \dot{x}, q)$$



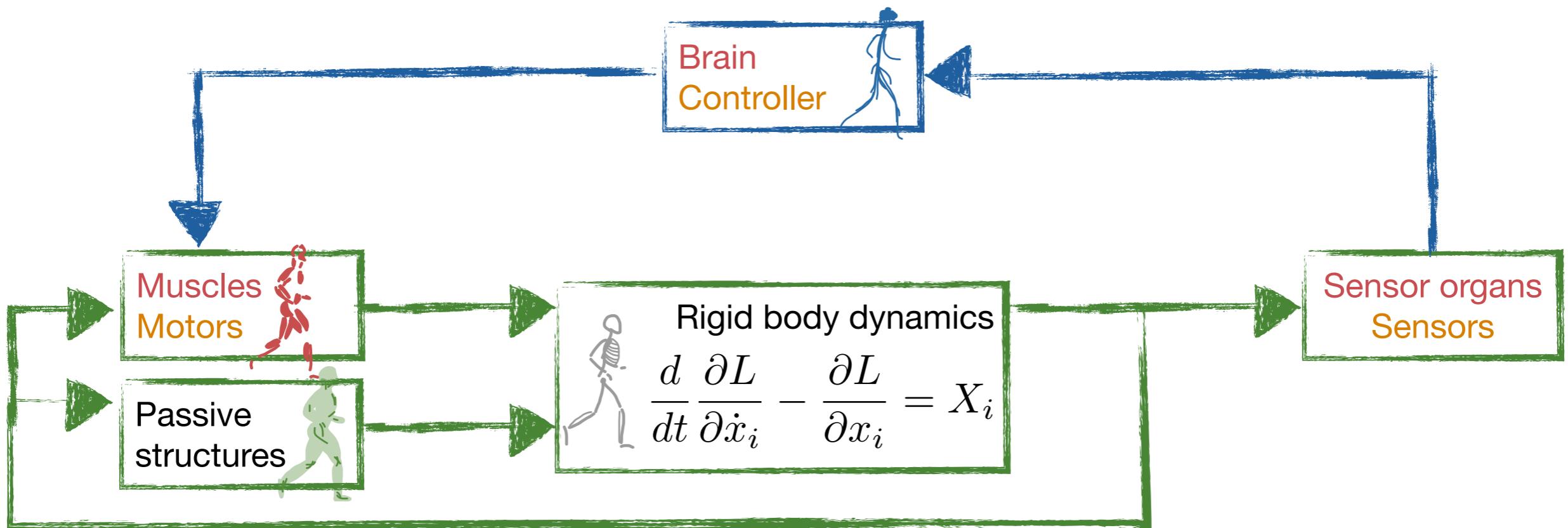
Neurons
Wires, CPU

Reflexes,
commands

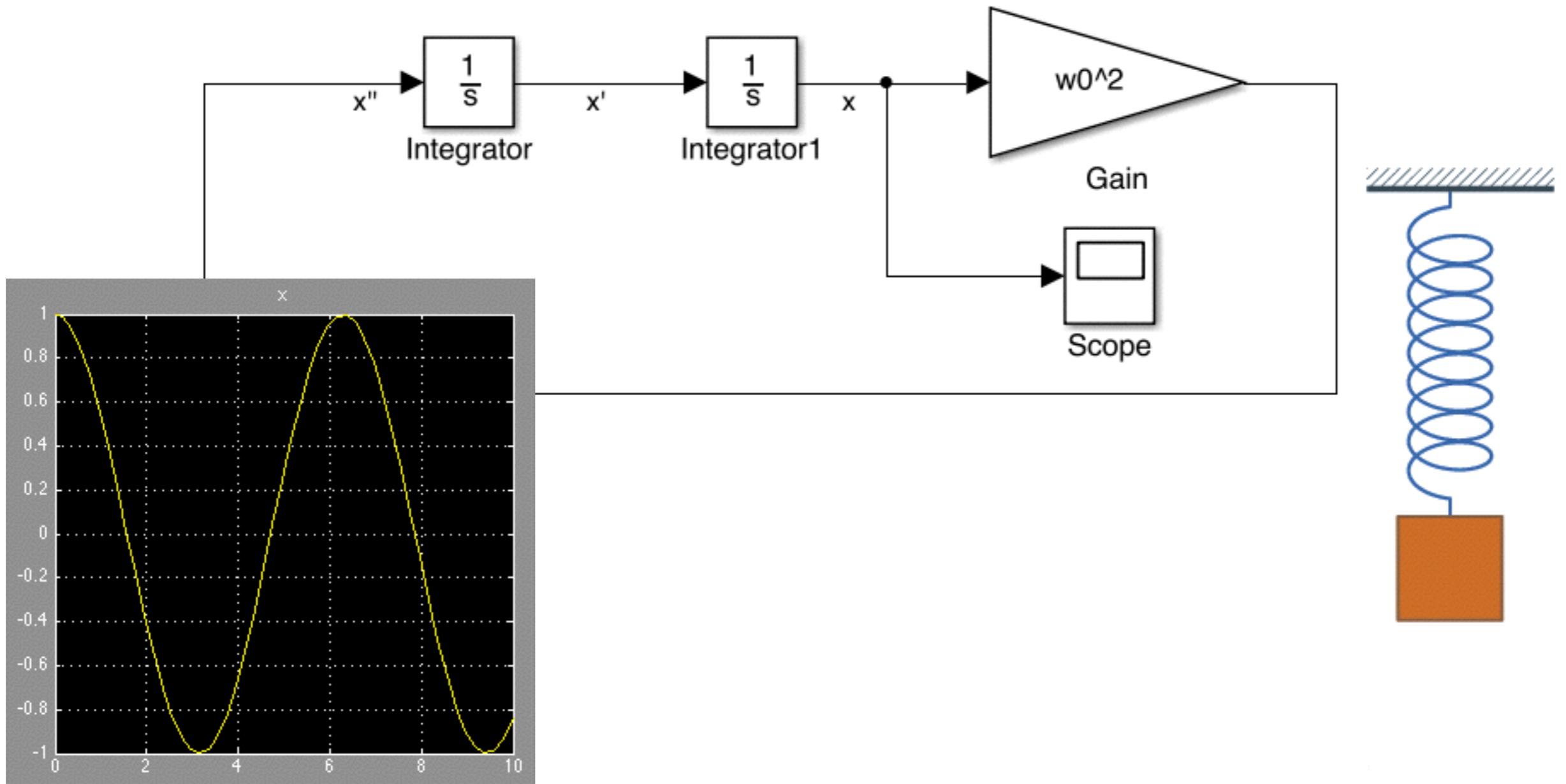
$$q = f(x, \dot{x})$$

$$q = f(\text{Brain})$$

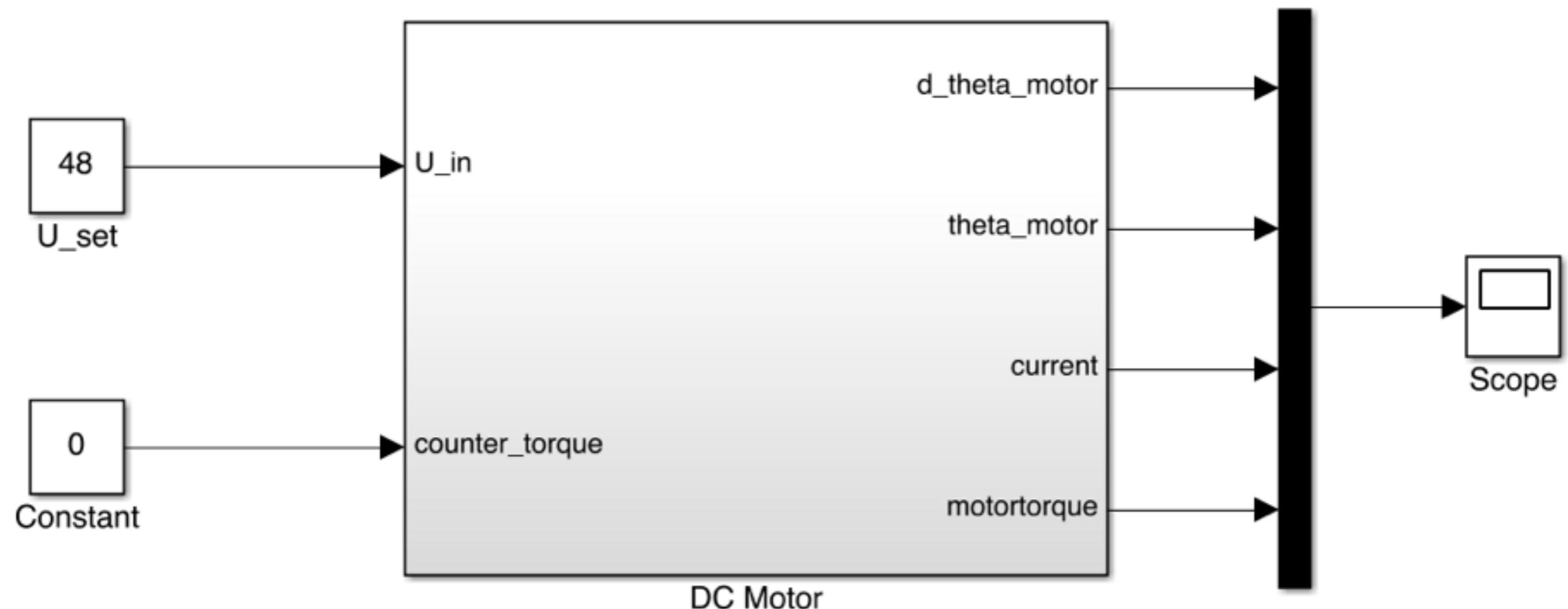
Synthesis of human movement



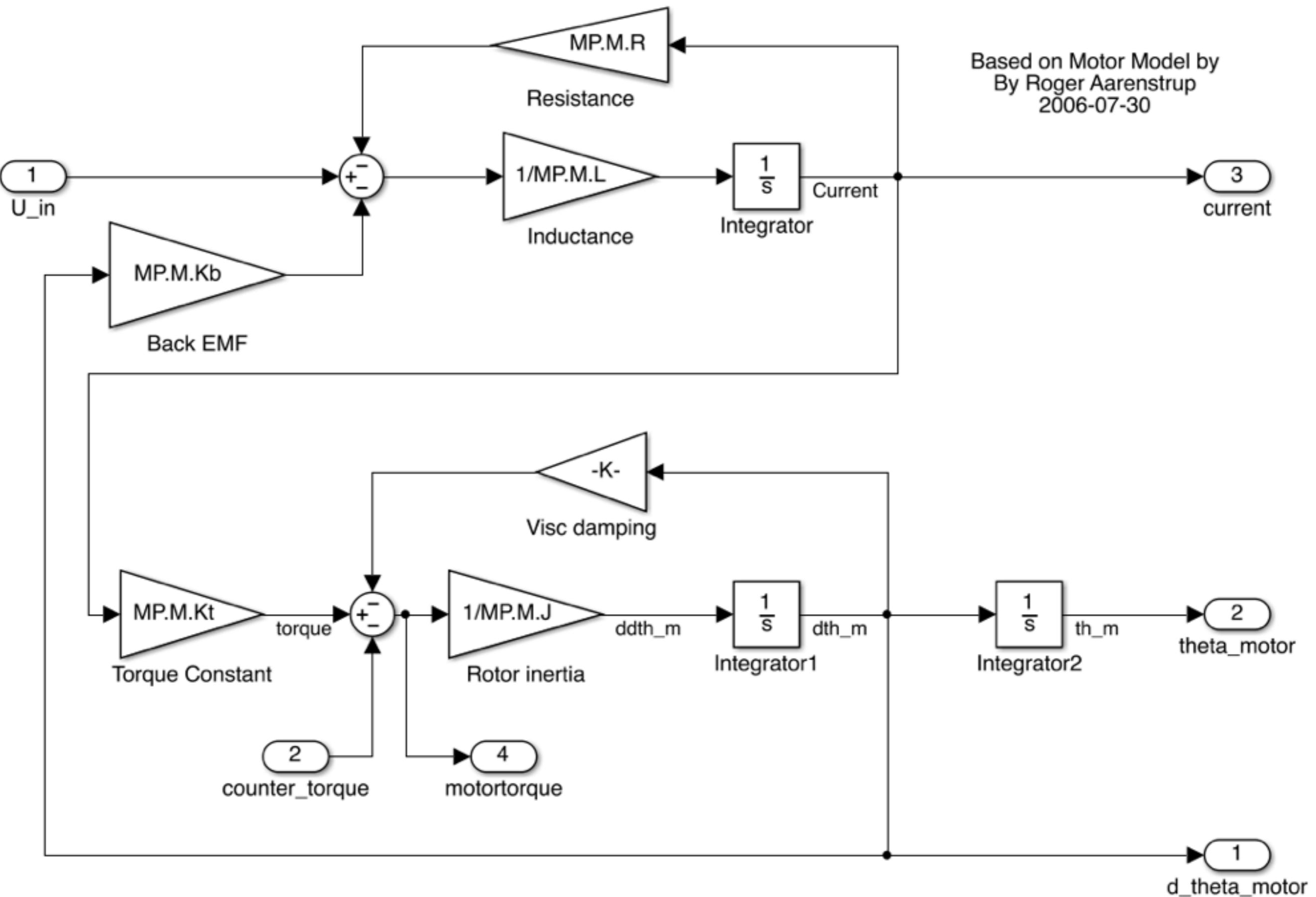
Beispiel 1

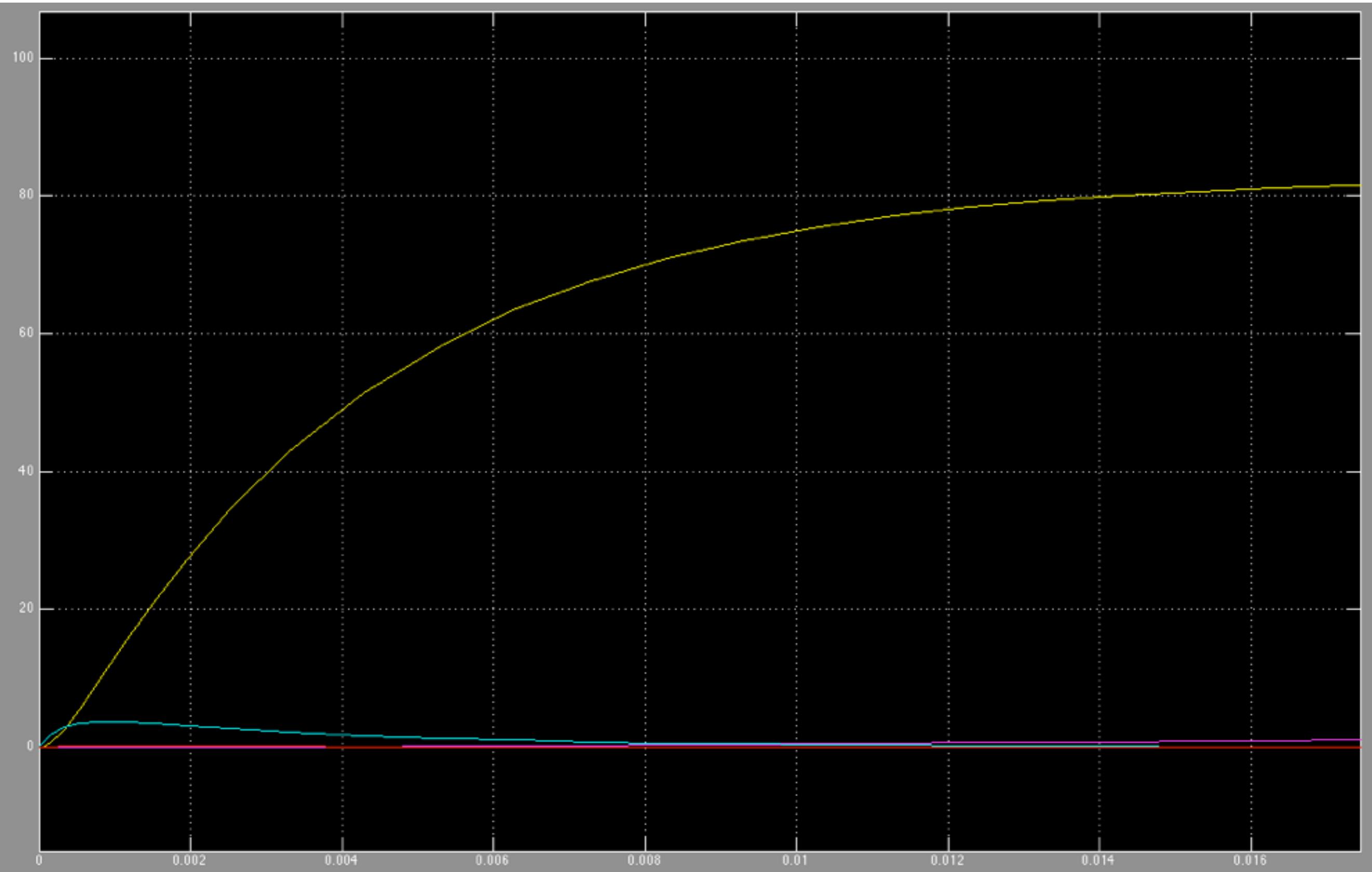


Beispiel2



Based on Motor Model by
By Roger Aarenstrup
2006-07-30

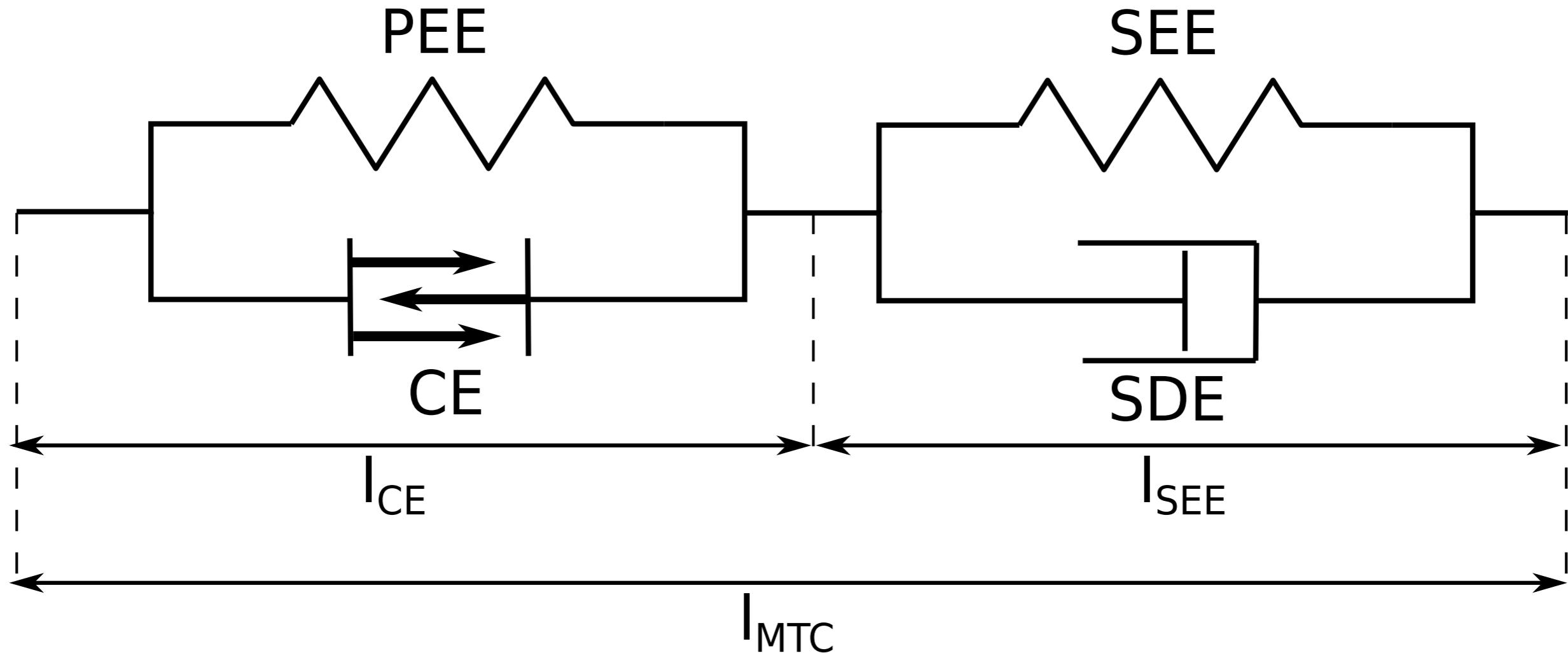




Muskelmodell: Struktur

Muscle model is published in and available through

Haeufle, D F B, M Günther, A Bayer, and S Schmitt. 2014. "Hill-Type Muscle Model with Serial Damping and Eccentric Force-Velocity Relation." *Journal of Biomechanics* 47 (6) 1531–1536
<http://dx.doi.org/10.1016/j.jbiomech.2014.02.009>

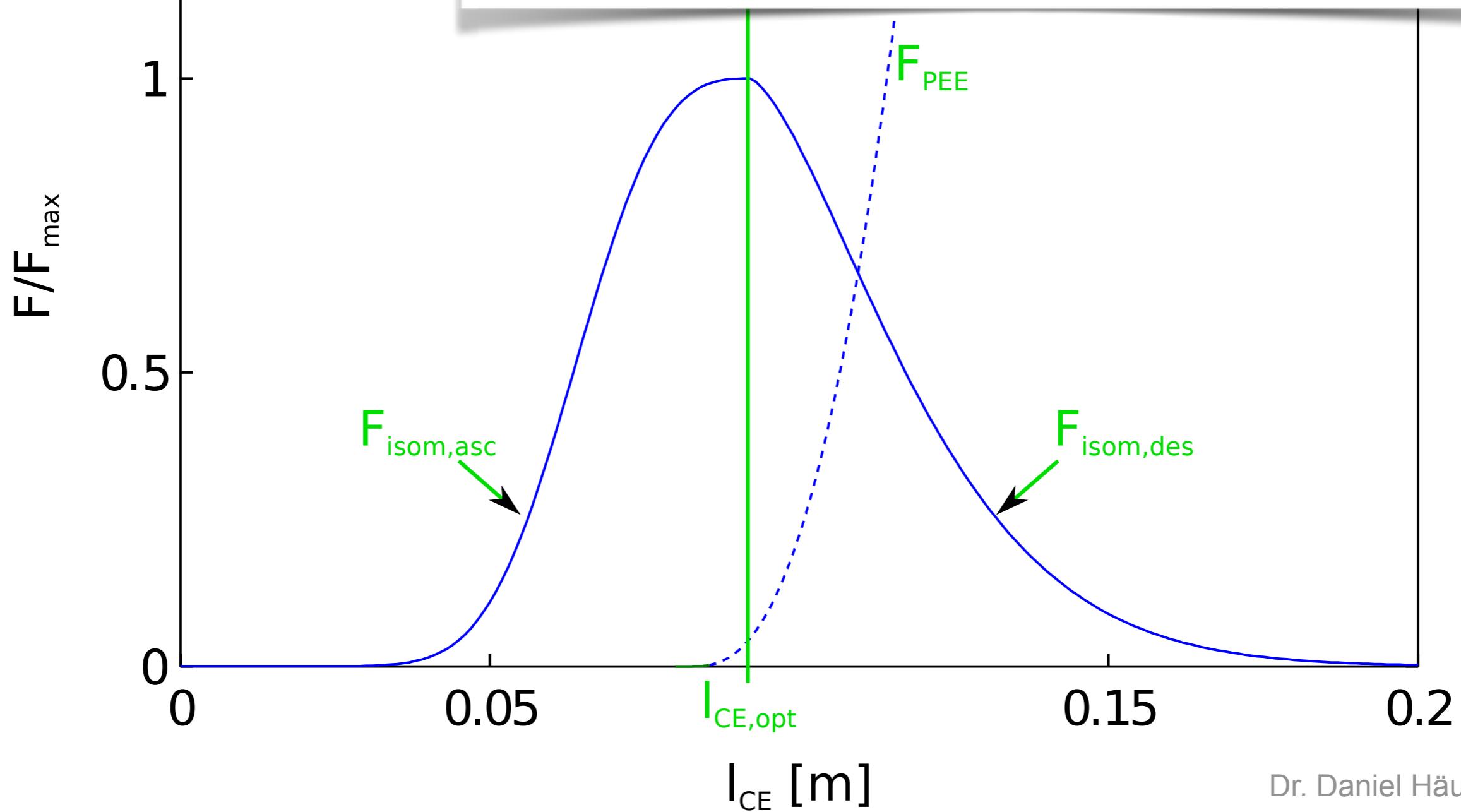


$$F_{CE}(l_{CE}, \dot{l}_{CE}, q) + F_{PEE}(l_{CE}) = F_{SEE}(l_{CE}, l_{MTC}) + F_{SDE}(l_{CE}, \dot{l}_{CE}, \dot{l}_{MTC}, q)$$

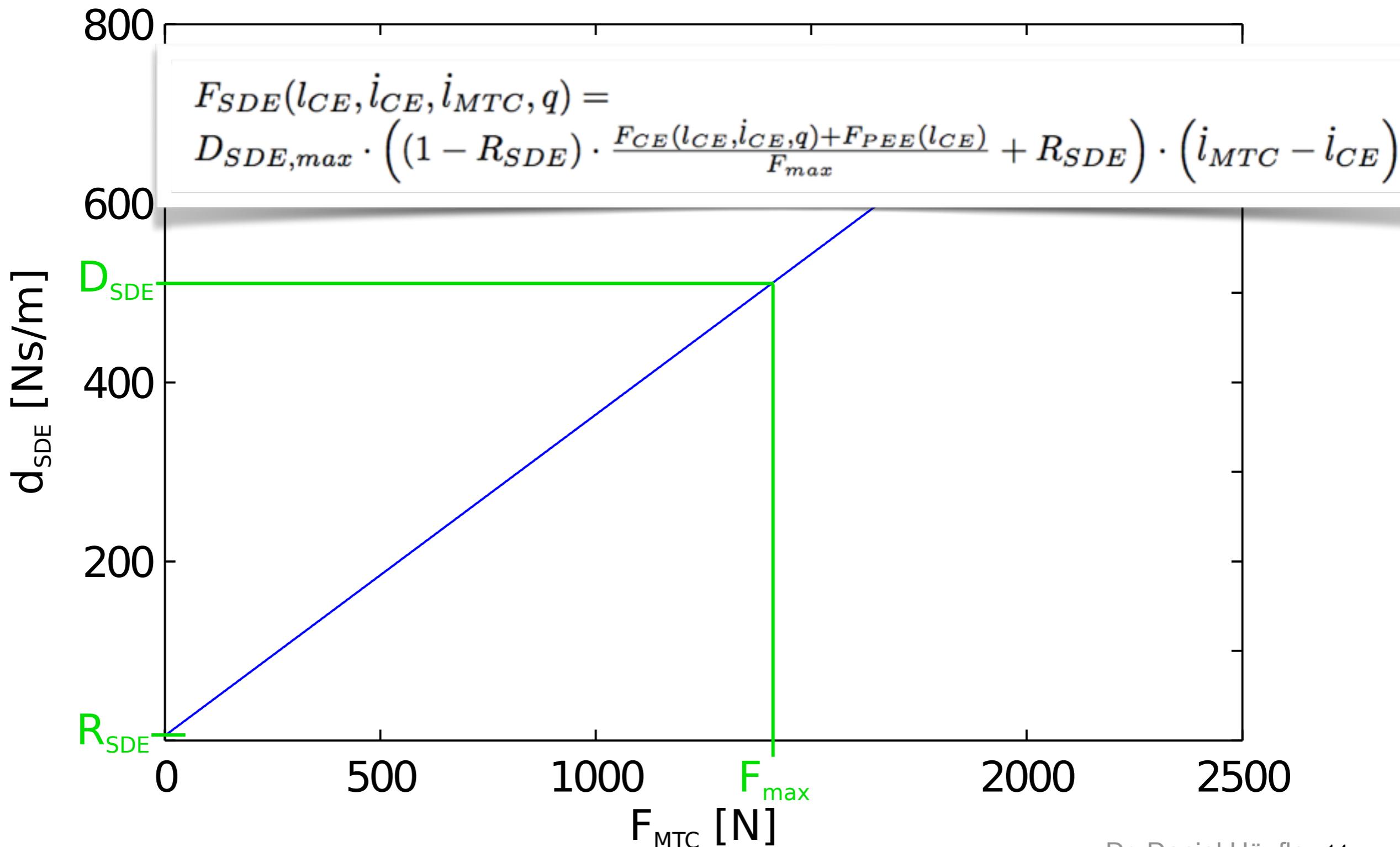
Muskelmodelle

$$F_{PEE}(l_{CE}) = \begin{cases} 0 & , l_{CE} < l_{PEE,0} \\ K_{PEE} (l_{CE} - l_{PEE,0})^{\nu_{PEE}} & , l_{CE} \geq l_{PEE,0} \end{cases}$$

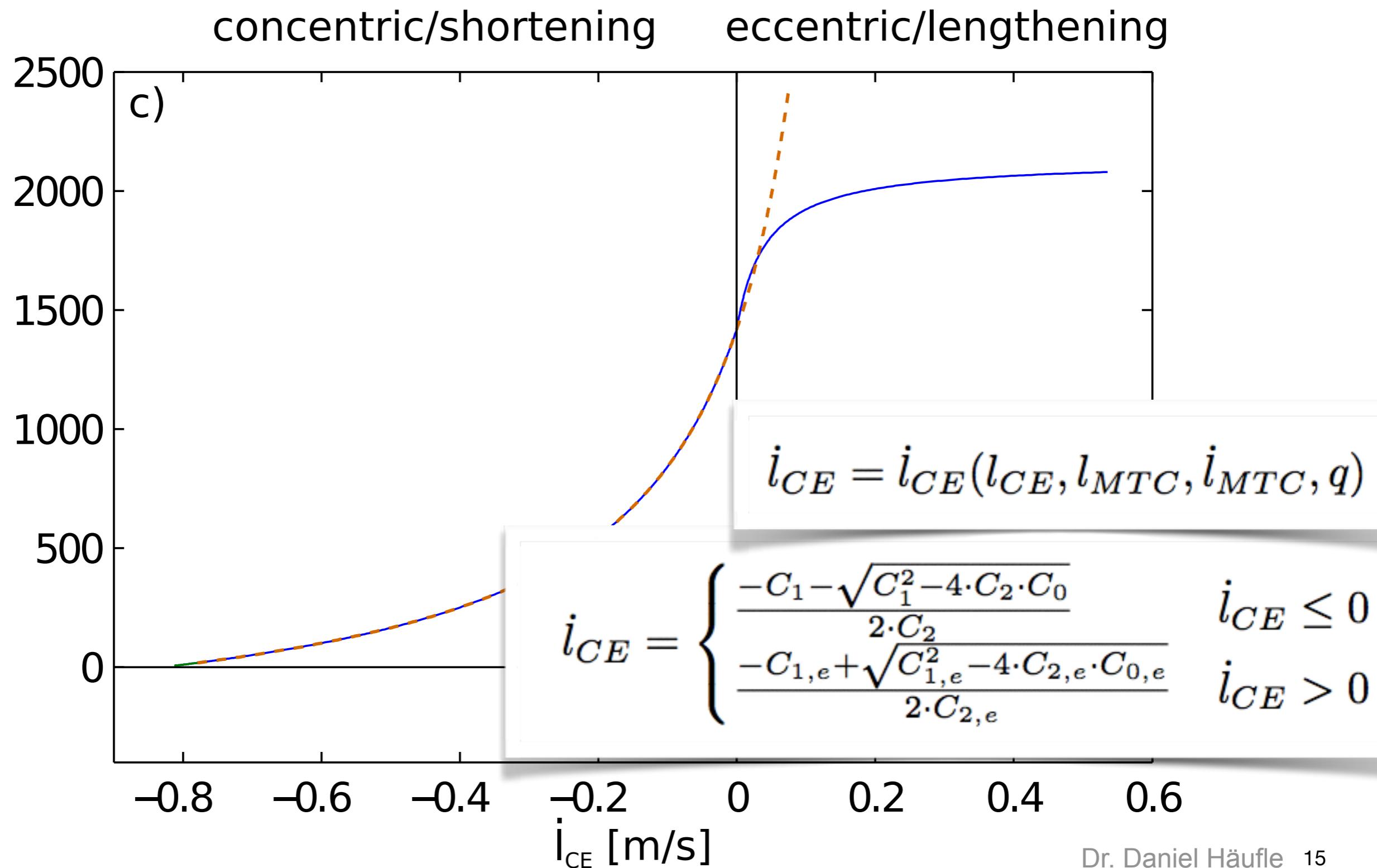
$$F_{isom}(l_{CE}) = \exp \left\{ - \left| \frac{l_{CE}/l_{CE,opt} - 1}{\Delta W_{limb}} \right|^{\nu_{CE,limb}} \right\}$$



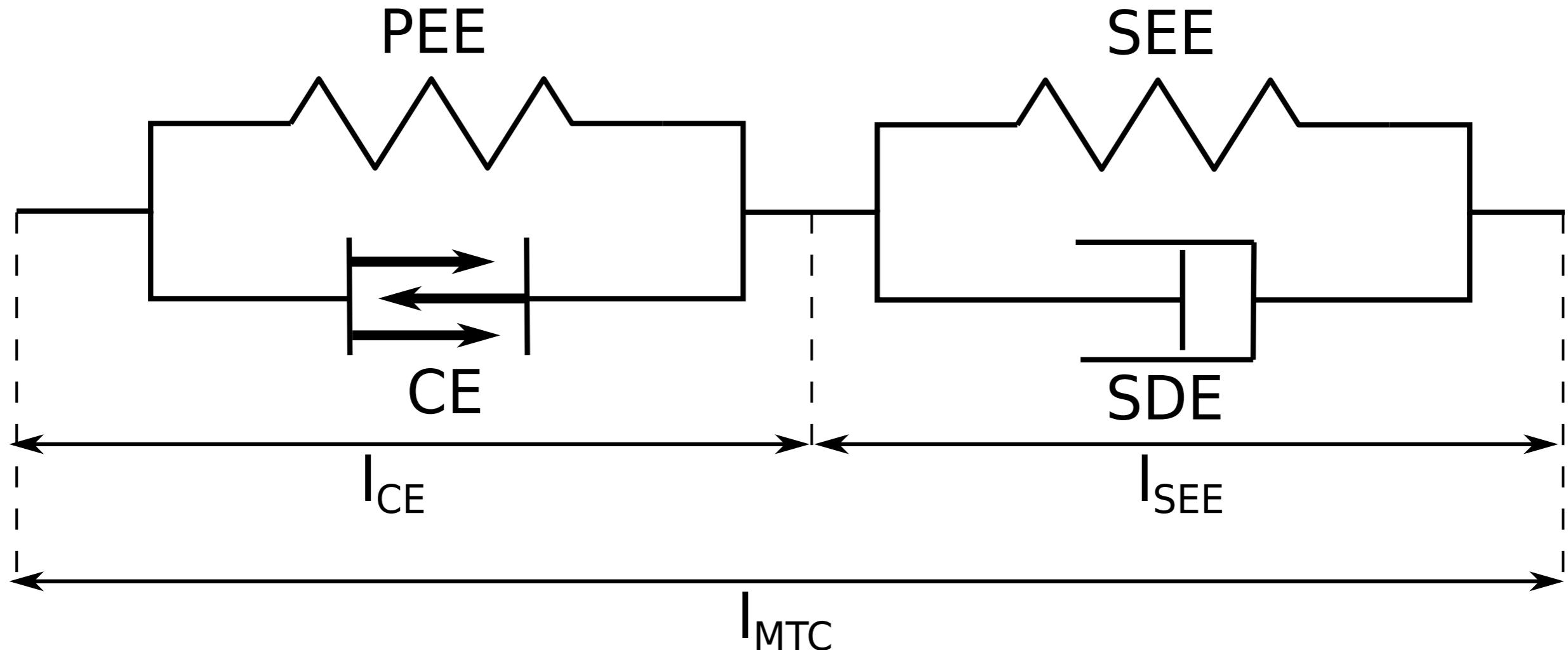
Muskelmodell



Muskelmodell

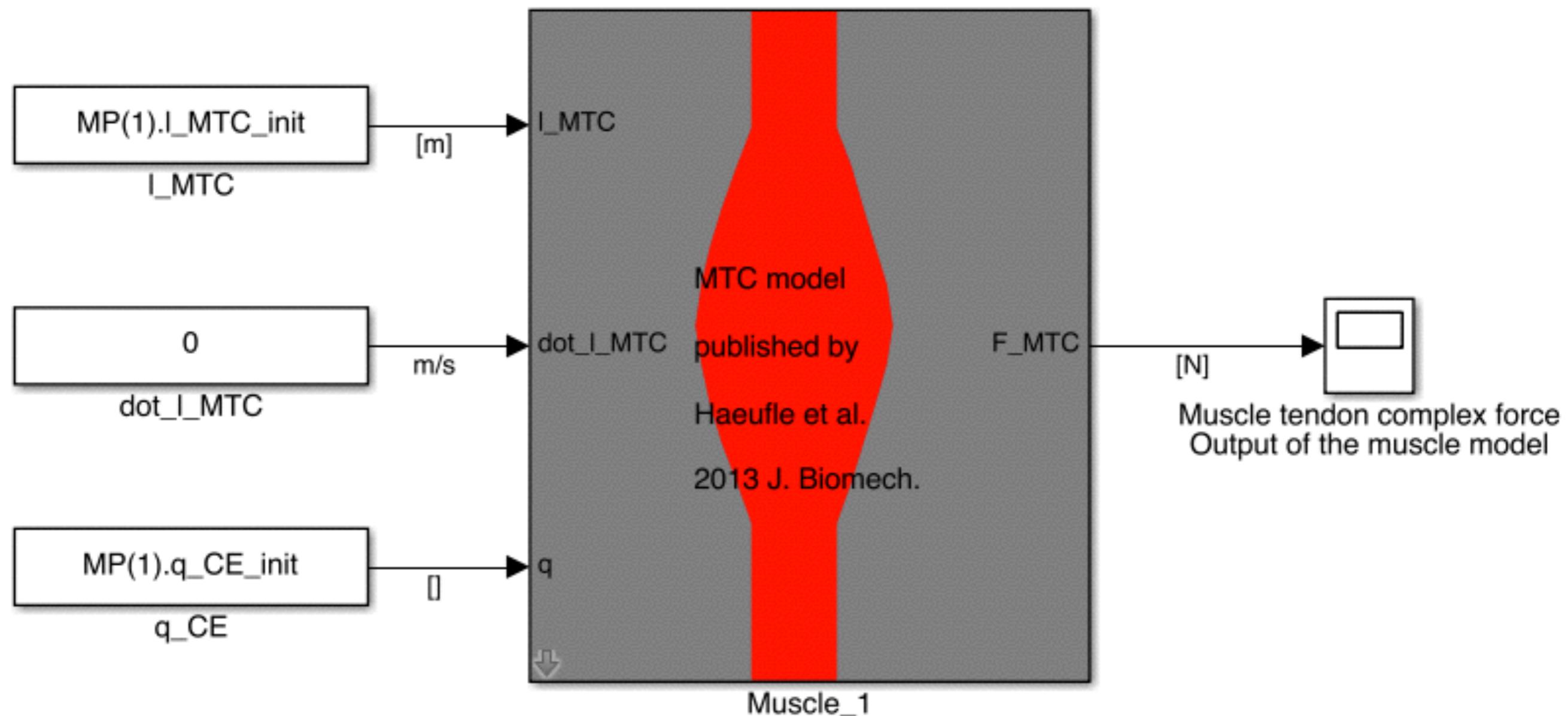


Muskelmodell: Struktur



$$\dot{l}_{CE} = \dot{l}_{CE}(l_{CE}, l_{MTC}, \dot{l}_{MTC}, q)$$

Muskelmodell



Muskelmodell

