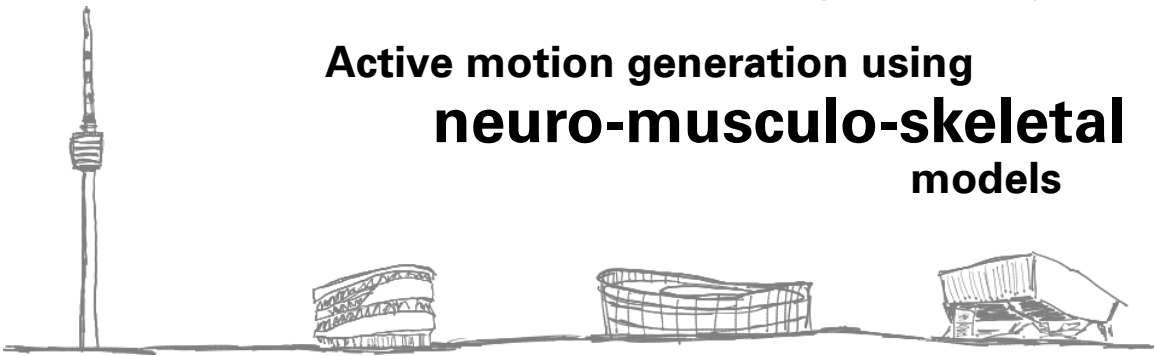
University of Stuttgart
Institute for Modelling and Simulation
of Biomechanical Systems

Syn Schmitt, February 06, 2020

Active motion generation using neuro-musculo-skeletal models



cbb Computational Biophysics and Biorobotics

QUT

imprs-is

SimTech

Cheetah (*Acinonyx jubatus*) chasing a springbok (*Antidorcas marsupialis*) • Smithsonian channel

A window into the functioning of the **central nervous system**?

(Schmitt, Günther, and Häufle 2019)

Model of high-level motor control

EP control

$$\Lambda_i^{\text{move}} = \{\vec{\lambda}_1, \vec{\lambda}_2, \vec{\lambda}_3, \ldots, \vec{\lambda}_n\}$$

Joint space control

continuous vs. intermittent

model-based control

learning-based control

Model of skeletal muscle

Hill-type model

$$F_j^{\text{MTU}} = f_f(l_j^{\text{MTU}}, \dot{l}_j^{\text{MTU}}, l_j^{\text{CE}}, a_j)$$

$$\dot{l}_j^{\text{CE}} = f_v(l_j^{\text{MTU}}, \dot{l}_j^{\text{MTU}}, l_j^{\text{CE}}, a_j)$$

$$\dot{a}_j = f_a(a_j, l_j^{\text{CE}}, u_j)$$

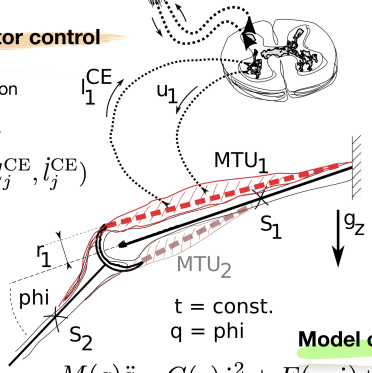
Model of low-level motor control

monosynaptic reflex

alpha-gamma co-activation

$$u_j = u_j^{\text{open}} + u_j^{\text{closed}}$$

$$u_j^{\text{closed}} = f_n(\kappa, \lambda_j^{\text{CE}}, l_j^{\text{CE}}, \dot{l}_j^{\text{CE}})$$



Numerical solution

$$\vec{q}(t) = ?$$

Parameters

Initial conditions

Model of skeletal structure

$$M(q)\ddot{q} = C(q)\dot{q}^2 + E(q,\dot{q}) + G(q) + R(q)F^{\text{MTU}}$$

SimTech

The **elementary biological drive**

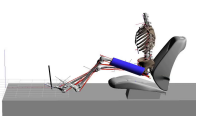
Learning? **Maybe, a rather naive and simple approach!**

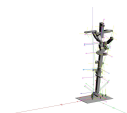
Given a specific control idea, learning is ...

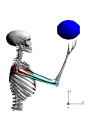
- finding appropriate **muscle stimulation pattern**, time to **change pattern**, etc., using *trial and error* (heuristics) or *fmincon* (gradient-based methods)
- **optimising controller** gains using *Bayesian optimisation*,

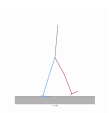
(Günther & Ruder, 2003)


(Bayer, 2017)


(Walter & Schmitt, 2012)


(Le Mouel, Martin et al., in prep)


(Suissa, 2018)


(Häufle et al., 2019)


(Driess et al., 2018)