Bio-inspired model for locomotion assistance

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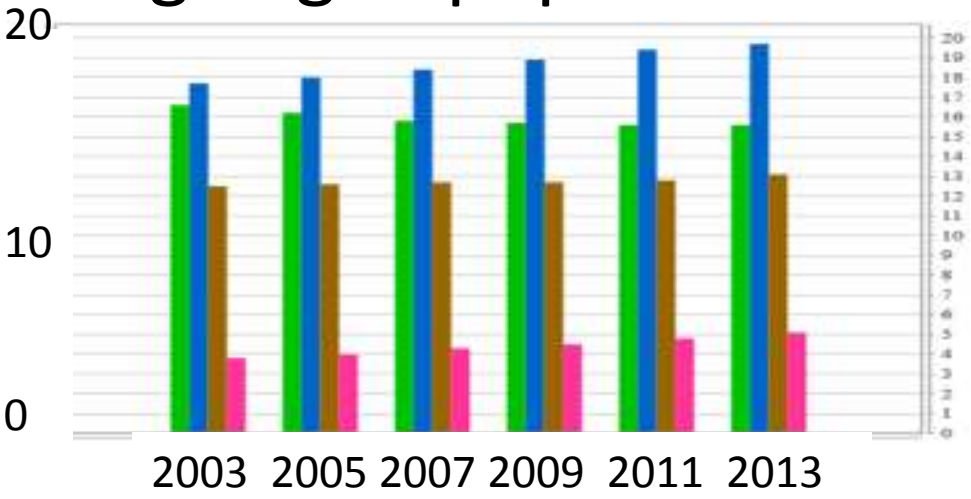
CYBERLEGs

Need of locomotion assistance

- Ageing of population



from Eurostat: demographic statistics

- Advance in medicine
- Dysvascular amputees

from Kessler Institute for rehabilitation

Bio- inspired model for locomotion assistance

- Manoeuvres
  - Walking

  - Stair ascending/descending

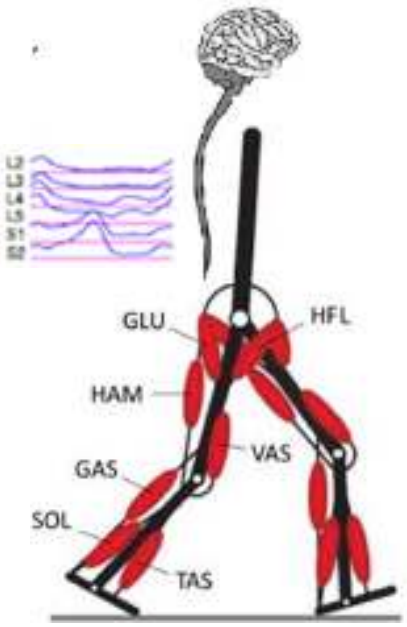
- Hypothesis: bio-inspired → less cognitive effort

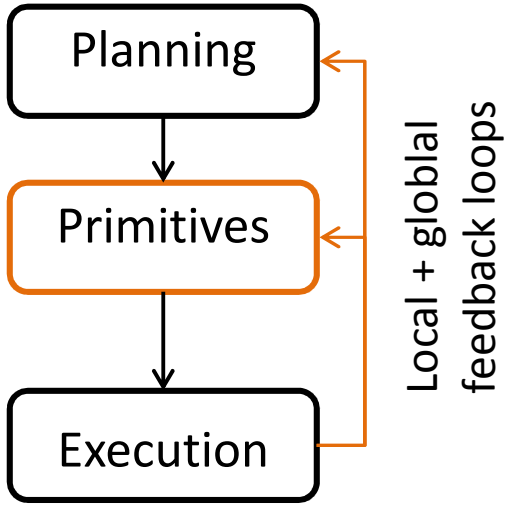
Outline

- Bio-inspired model
- Control model
- Off-line model Results
- Preliminary experiments
- Conclusions and on-going work

Bio-inspired model

- Copy natural dynamic of the muscles
- How to activate muscles?



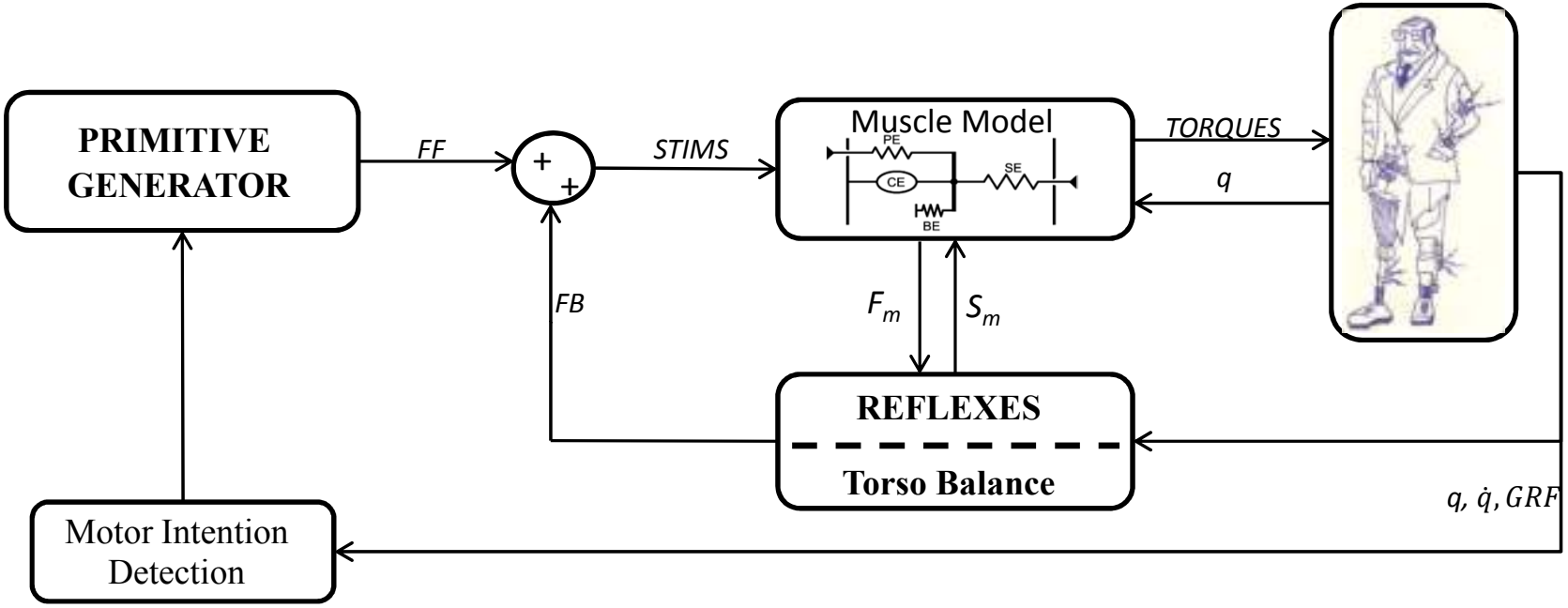


Adapted from: Geyer and Herr (2010), Capellini et al. (2010) and Dégallier et al. (2011)

Outline

- Control model
  - General control scheme
  - The muscle model
  - Feedback stimulations
  - Feed-forward stimulations

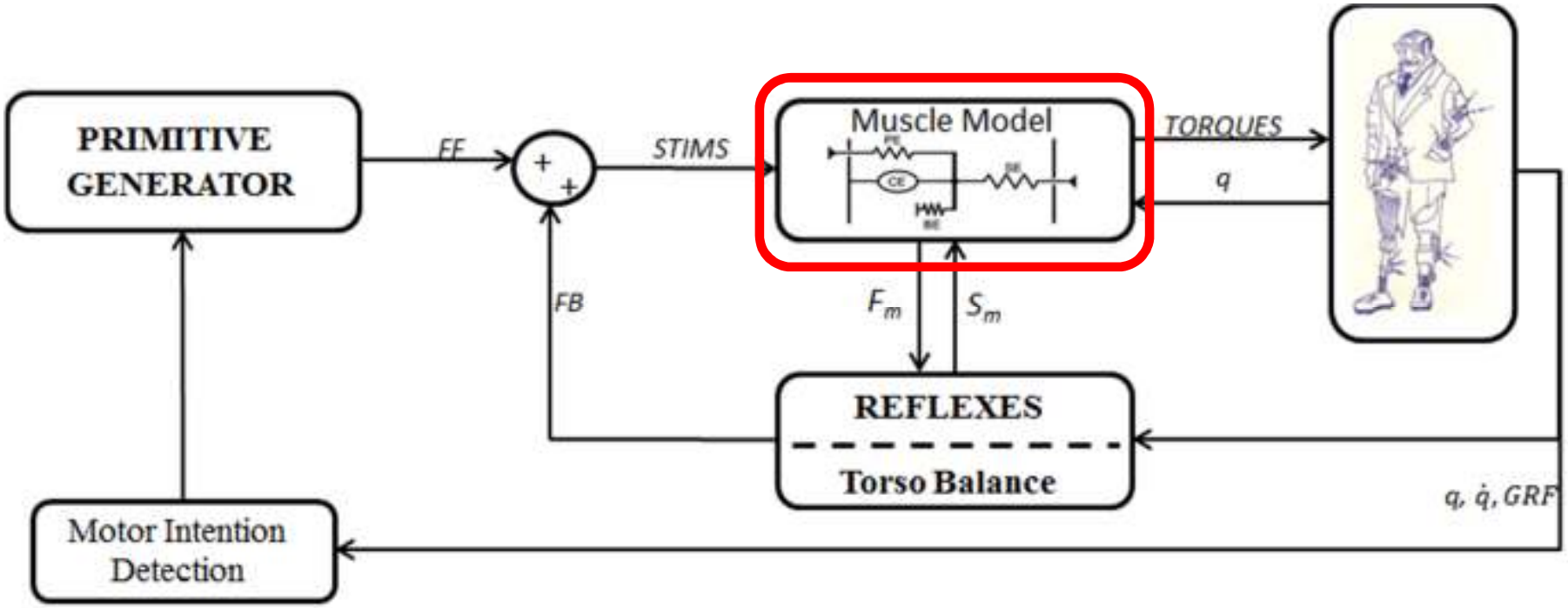
Primitives (FF) + Reflexes (FB)



- Predictive and adaptive

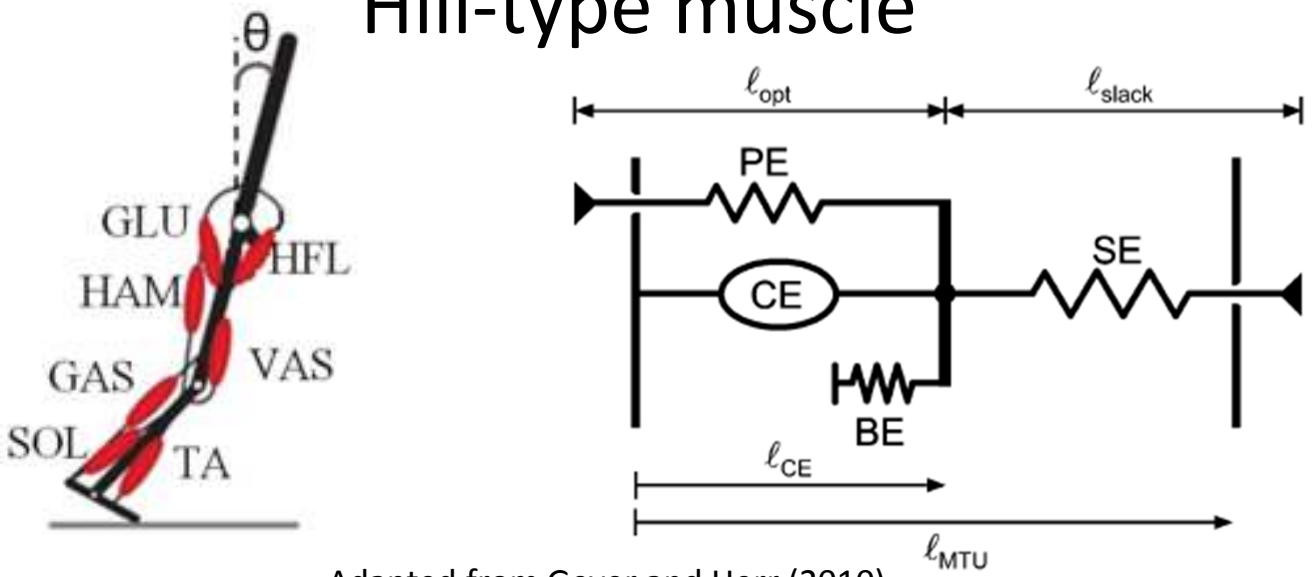
Outline

- Control model
  - The muscle model



The muscle model

Hill-type muscle



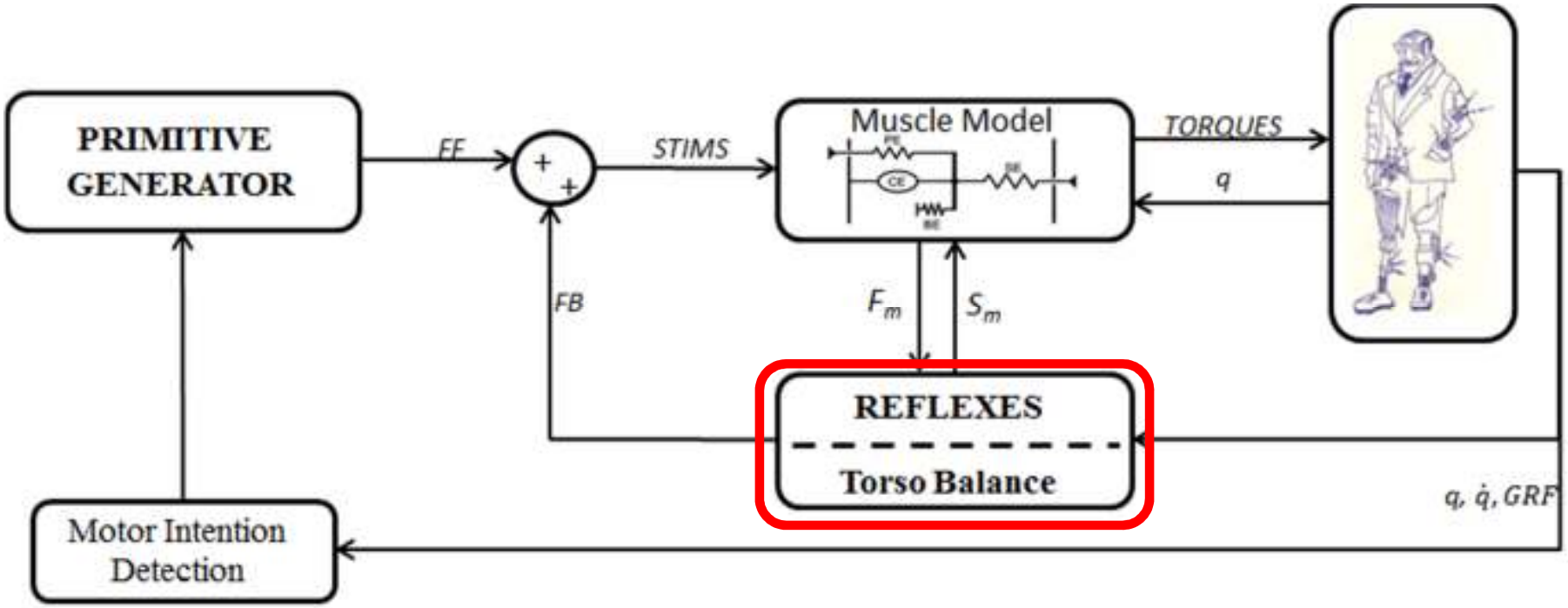
Adapted from Geyer and Herr (2010)

$$F_m = F_{se} = F_{ce} + F_{pe} - F_{be}$$
$$F_{ce} = AF_{max} f_l(lce) f_v(vce)$$

$$\tau_m = r_m(\varphi) F_m$$

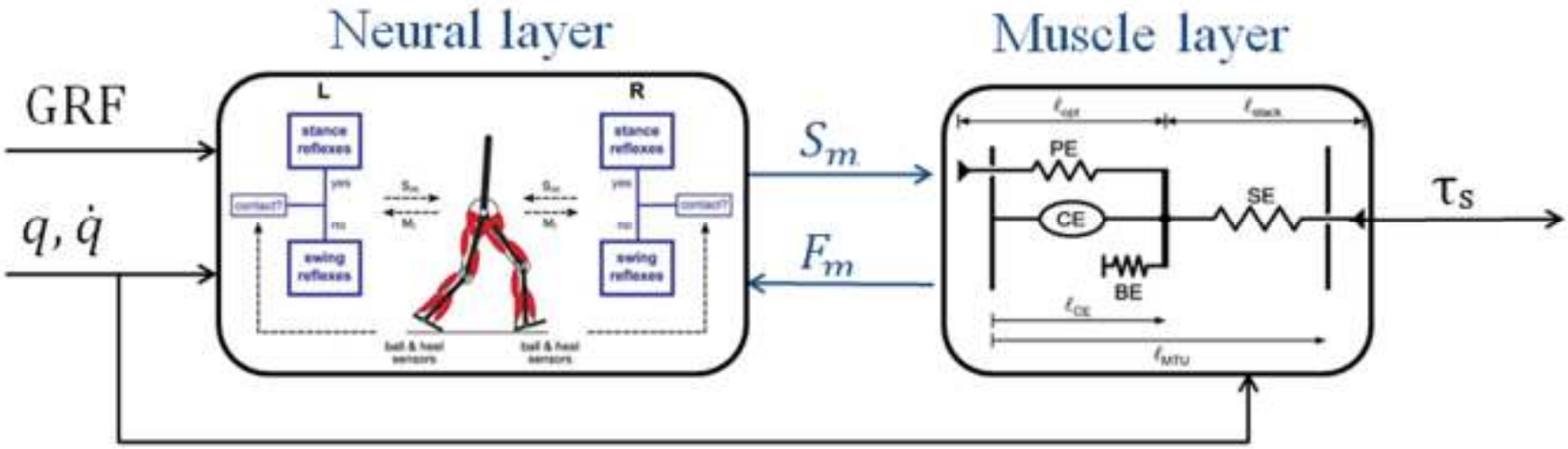
Outline

- Control model
  - Feedback stimulations



Short-loop reflexes

- Geyer and Herr (2010)



$$S_m(t) = S_{0,m} + G_m F_m(t - \Delta t_m)$$

- Additional terms

$$S_{VAS} = S_{0,VAS} + G_{VAS} F_{VAS}(t - \Delta t_{VAS}) - k_\varphi \Delta_{\varphi k}(t - \Delta t_k) - k_{bw} \left| F_{leg}^{contra} \right|$$

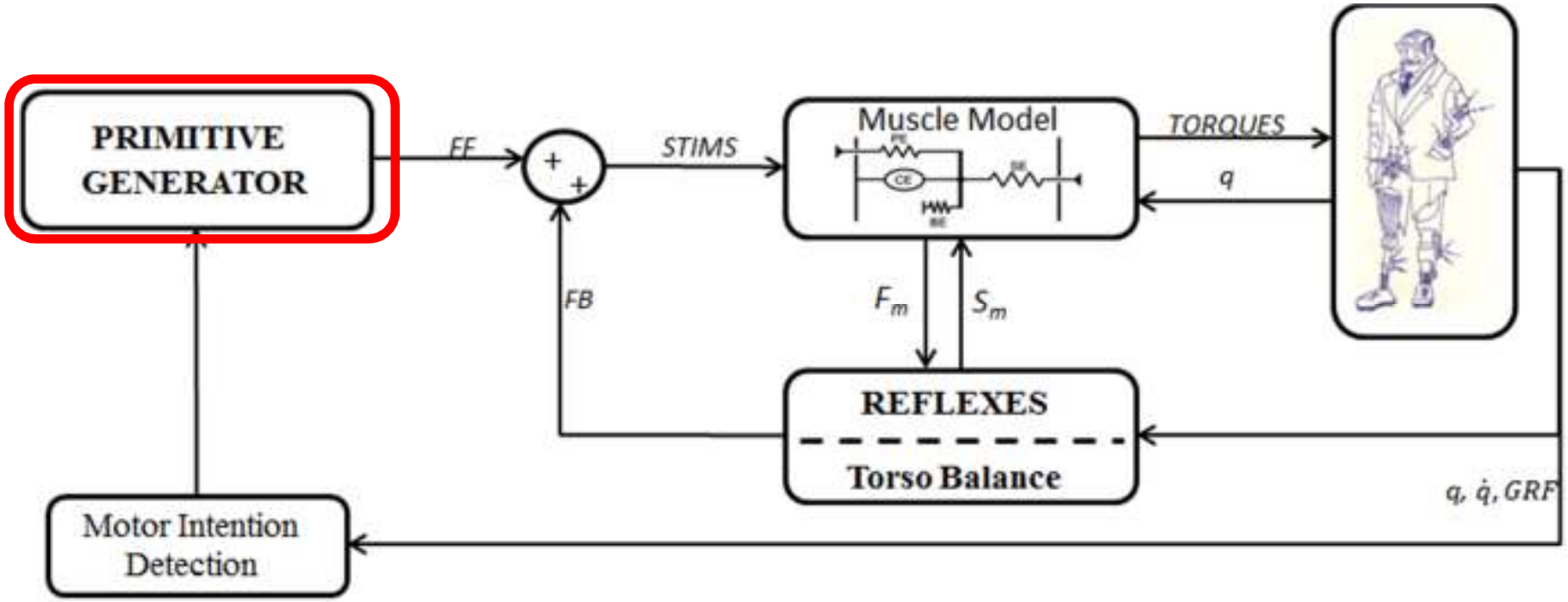
Torso Balance Control

- Inverted Pendulum
- Proportional-Derivative Controller

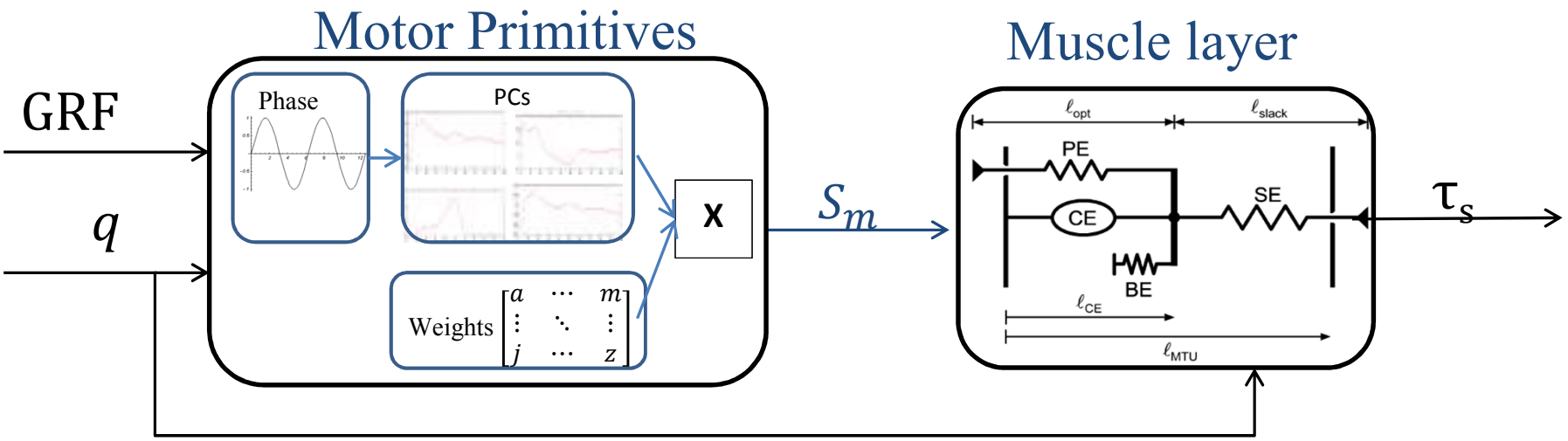
$$S_m(t) = Load[K_{p,m}(\theta - \theta_{ref}) + K_{d,m}\dot{\theta}]_{\substack{\Delta\theta<0 \\ \Delta\theta>0}}$$

Outline

- Control model
  - Feed-forward stimulations

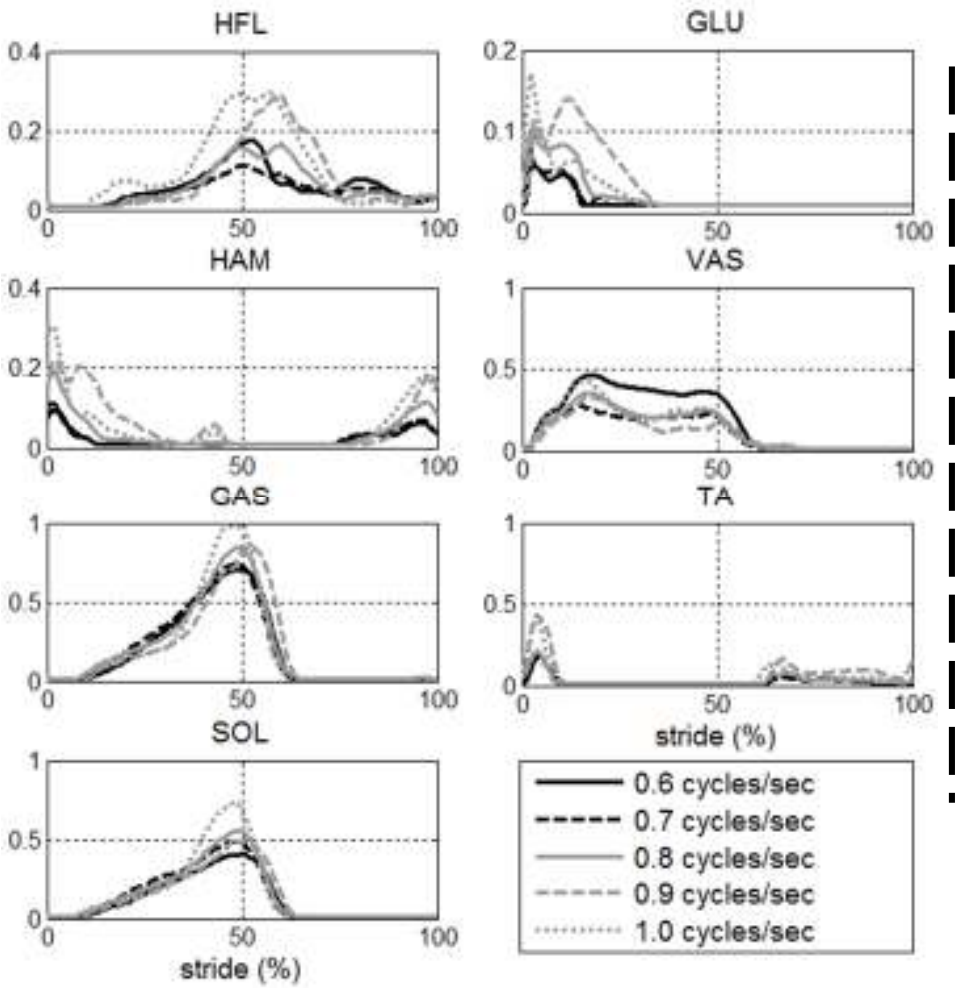


Feed-forward Primitives

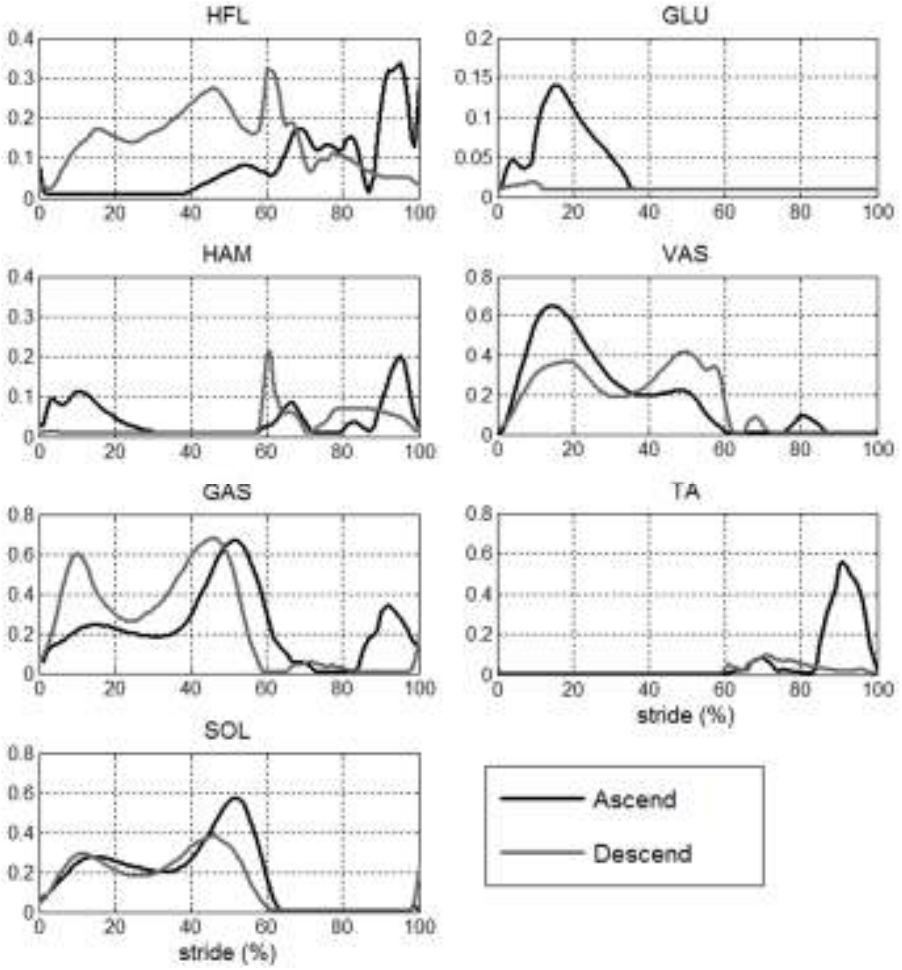


Muscle Stimulations

- Walking

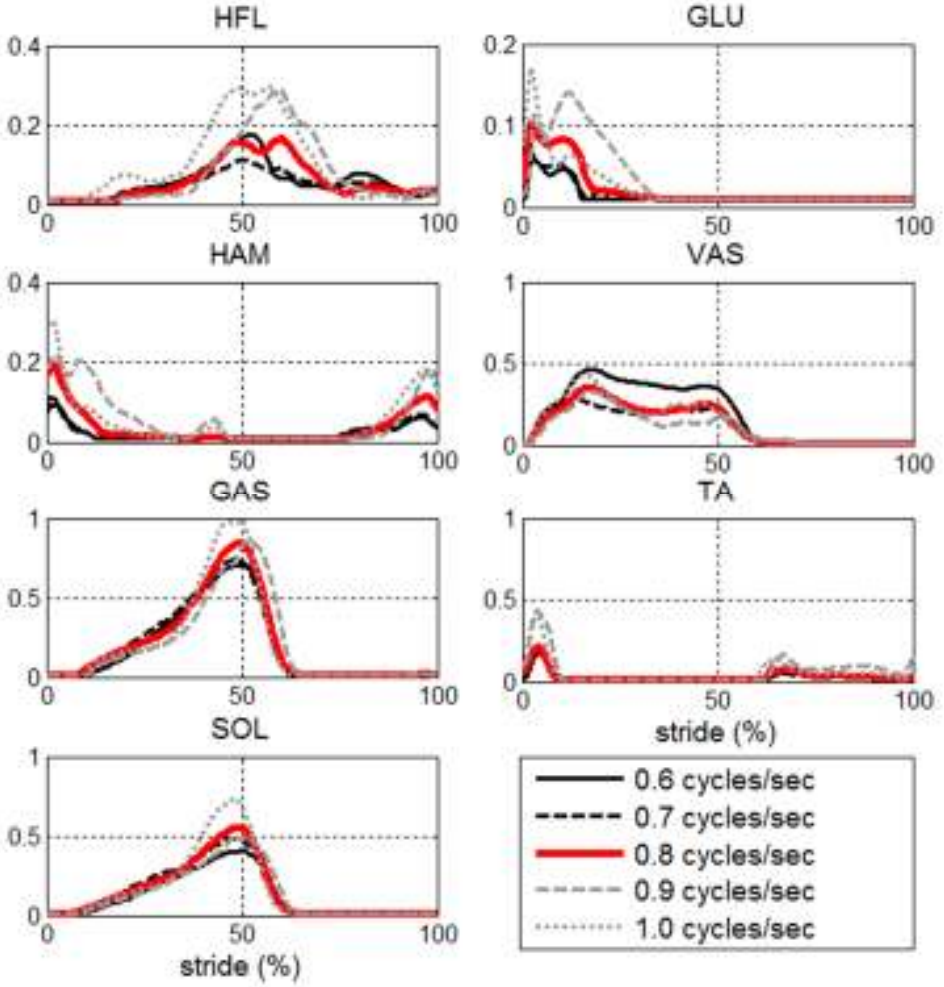


- Stairs

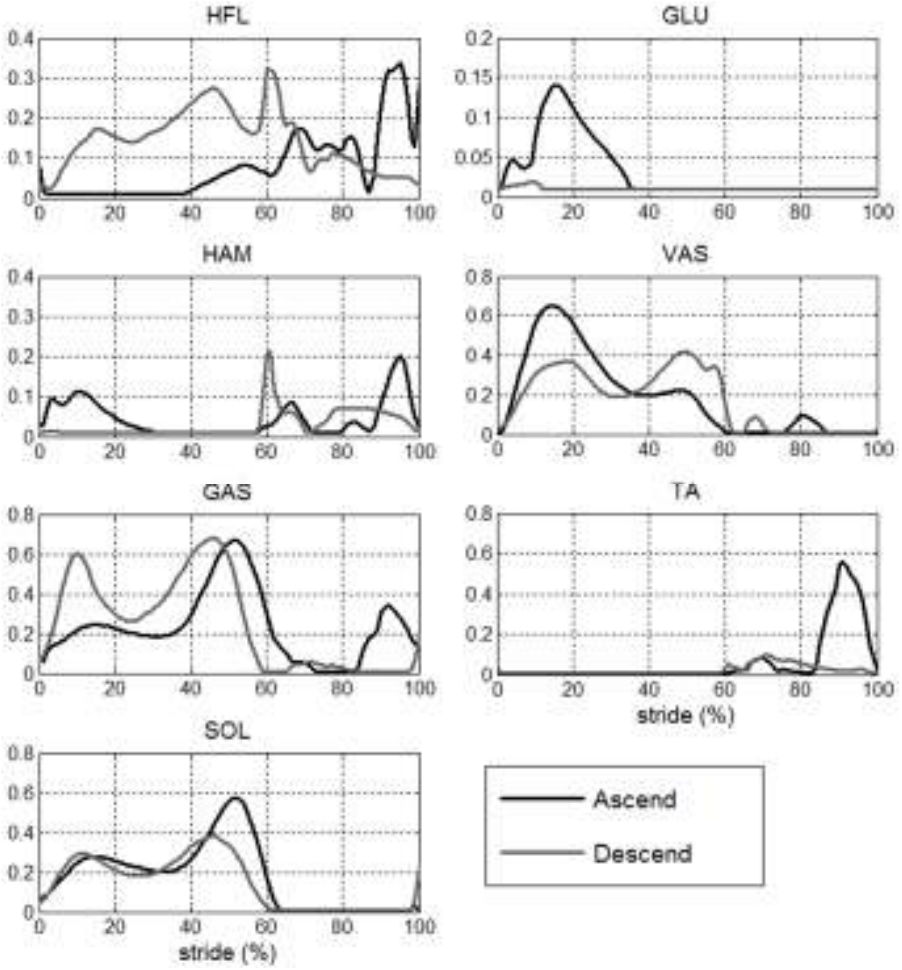


Muscle Stimulations

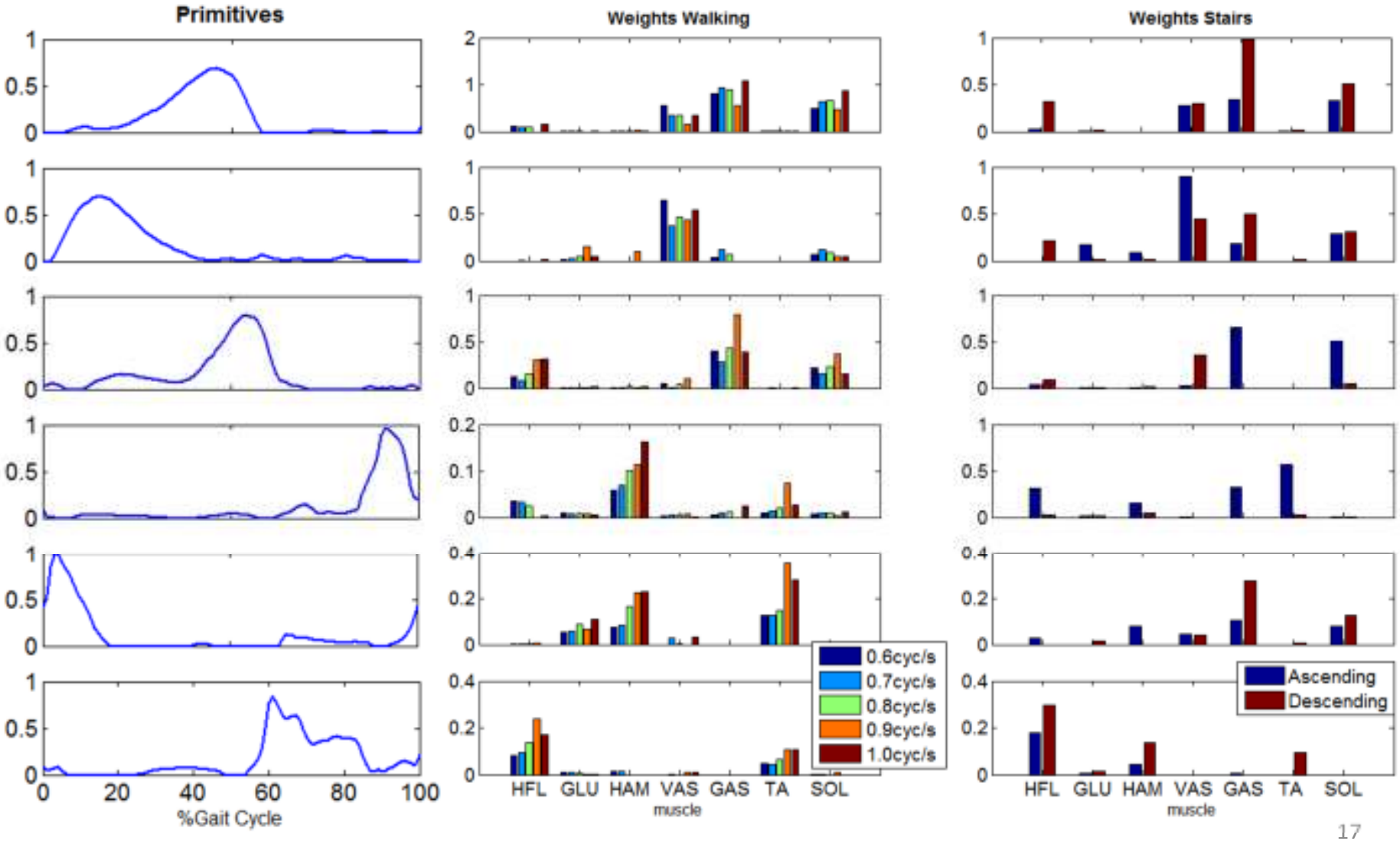
- Walking



- Stairs

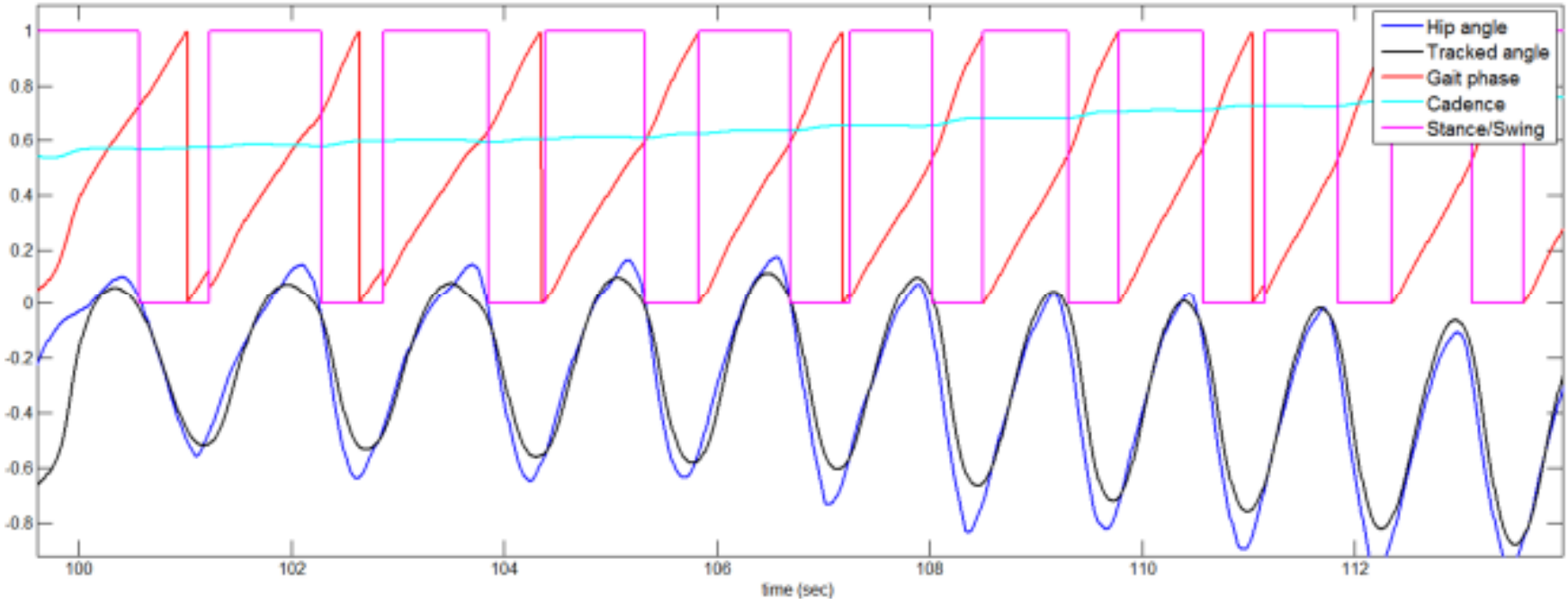


Primitives and Weights



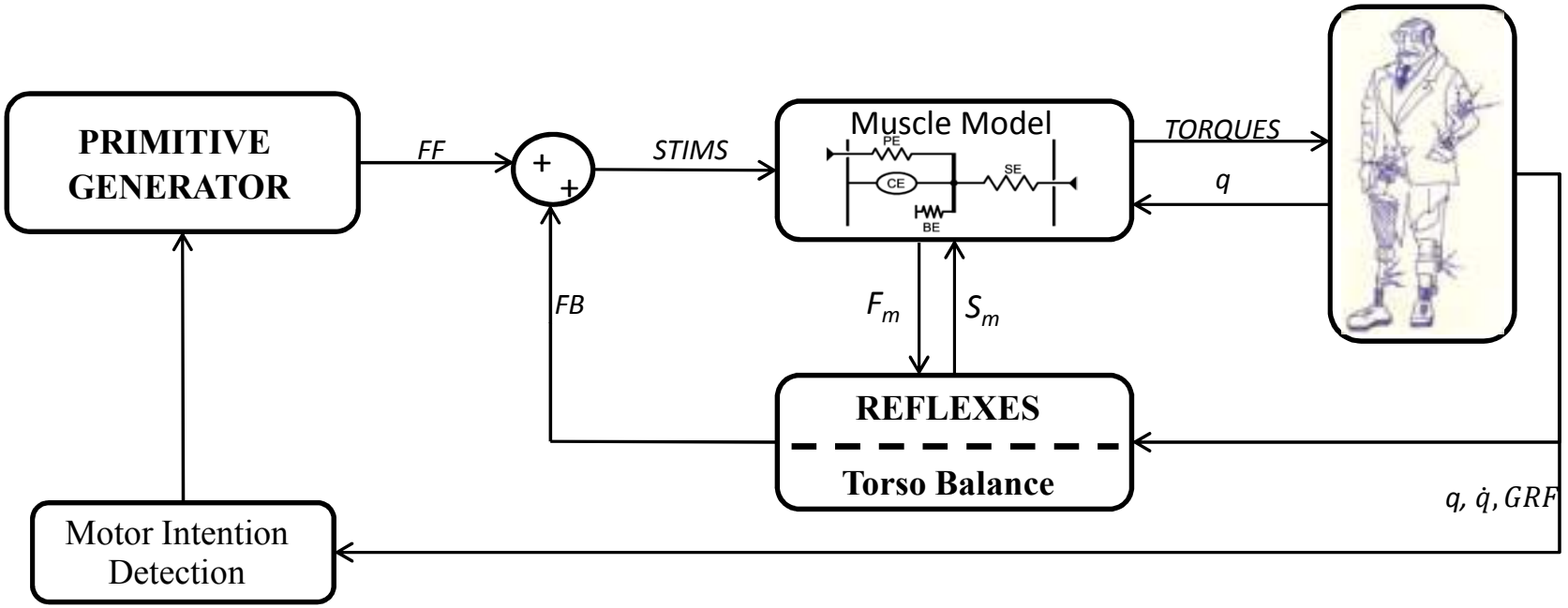
Phase synchronization

- Cyclic inputs
- Adaptive oscillators (Ronsse et al. , 2012; Righetti et al., 2006)



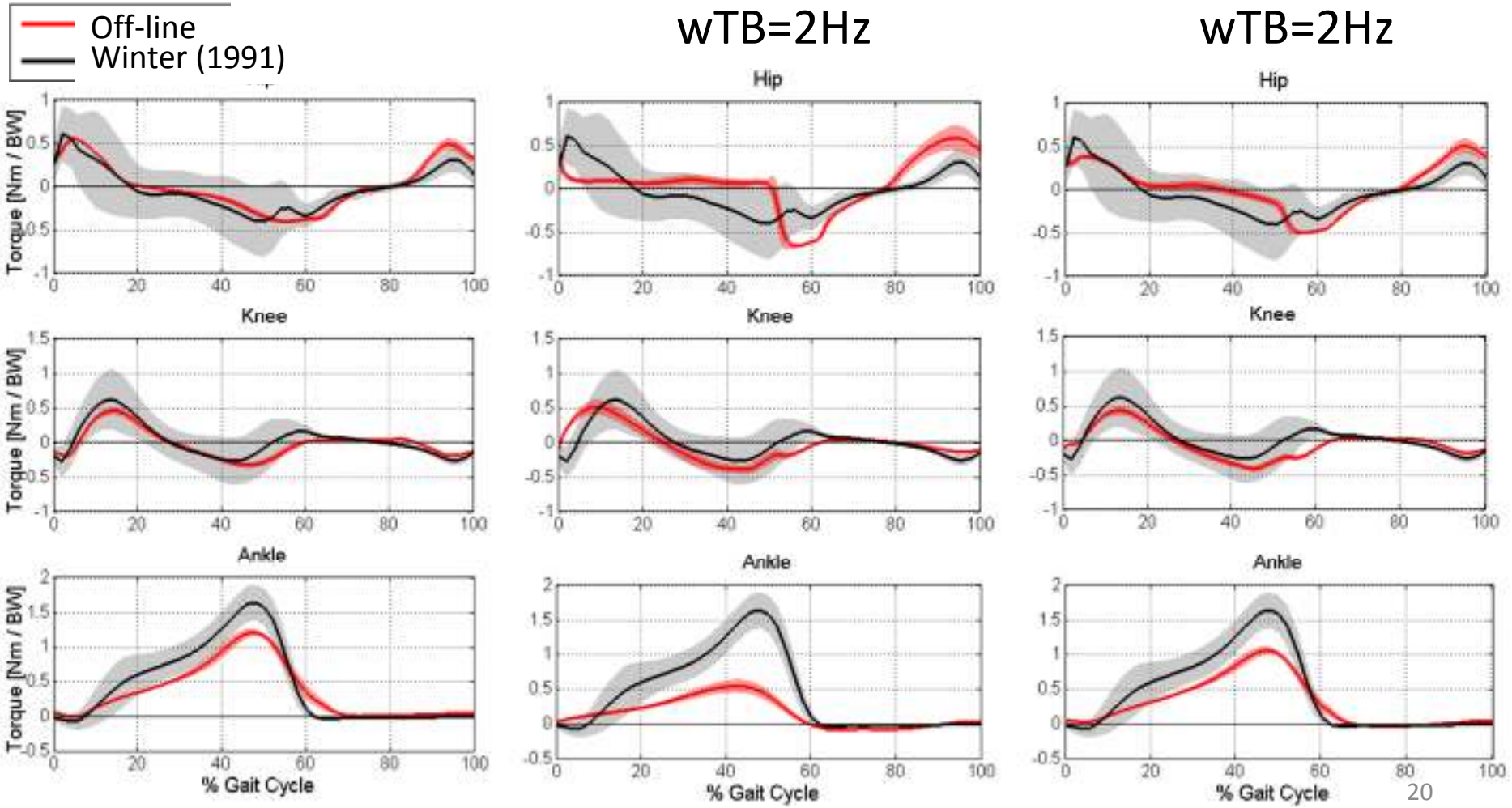
Outline

- Off-line model Results



Walking

- FF 100%
- FB 100% + wTB=2Hz
- FF 60% + FB 40% + wTB=2Hz

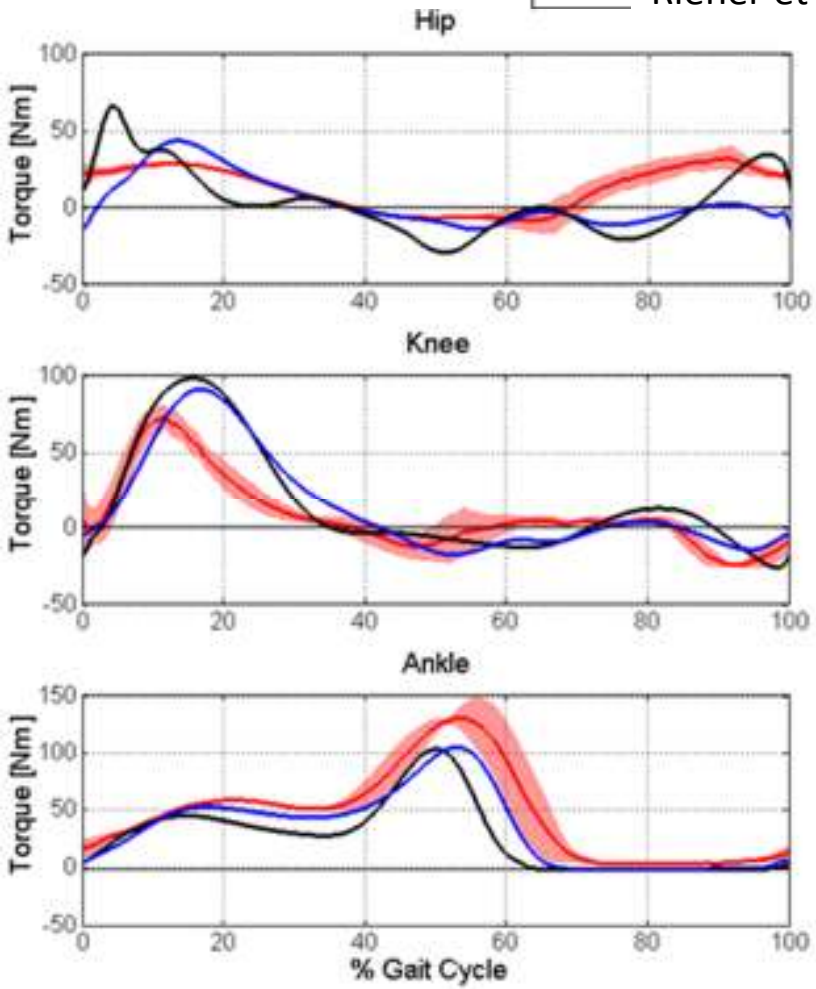


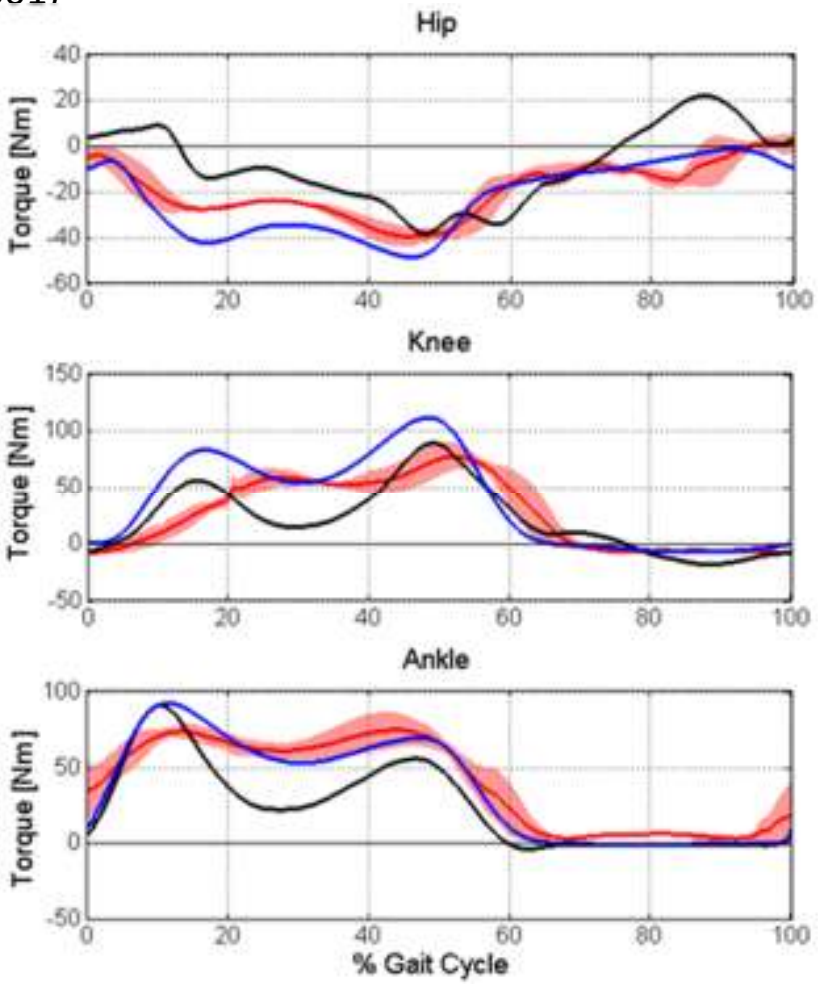
Stair ascending / descending

- Ascending

Off-line
Bradford et al. (1988)
Riener et al. (2001)

- Descending





Outline

- Preliminary experiments

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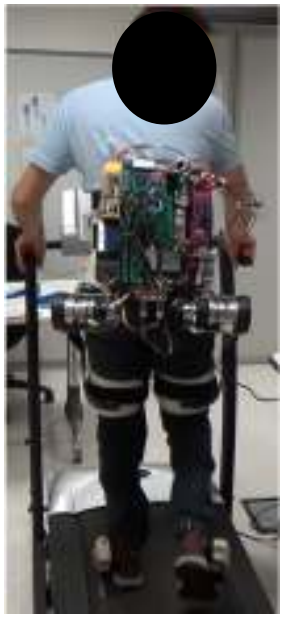
Vrije Universiteit Brussel

Fondazione Don Carlo Gnocchi Onlus

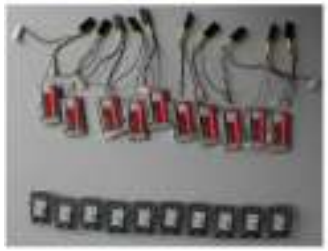
University of Ljubljana

CYBERLEGs

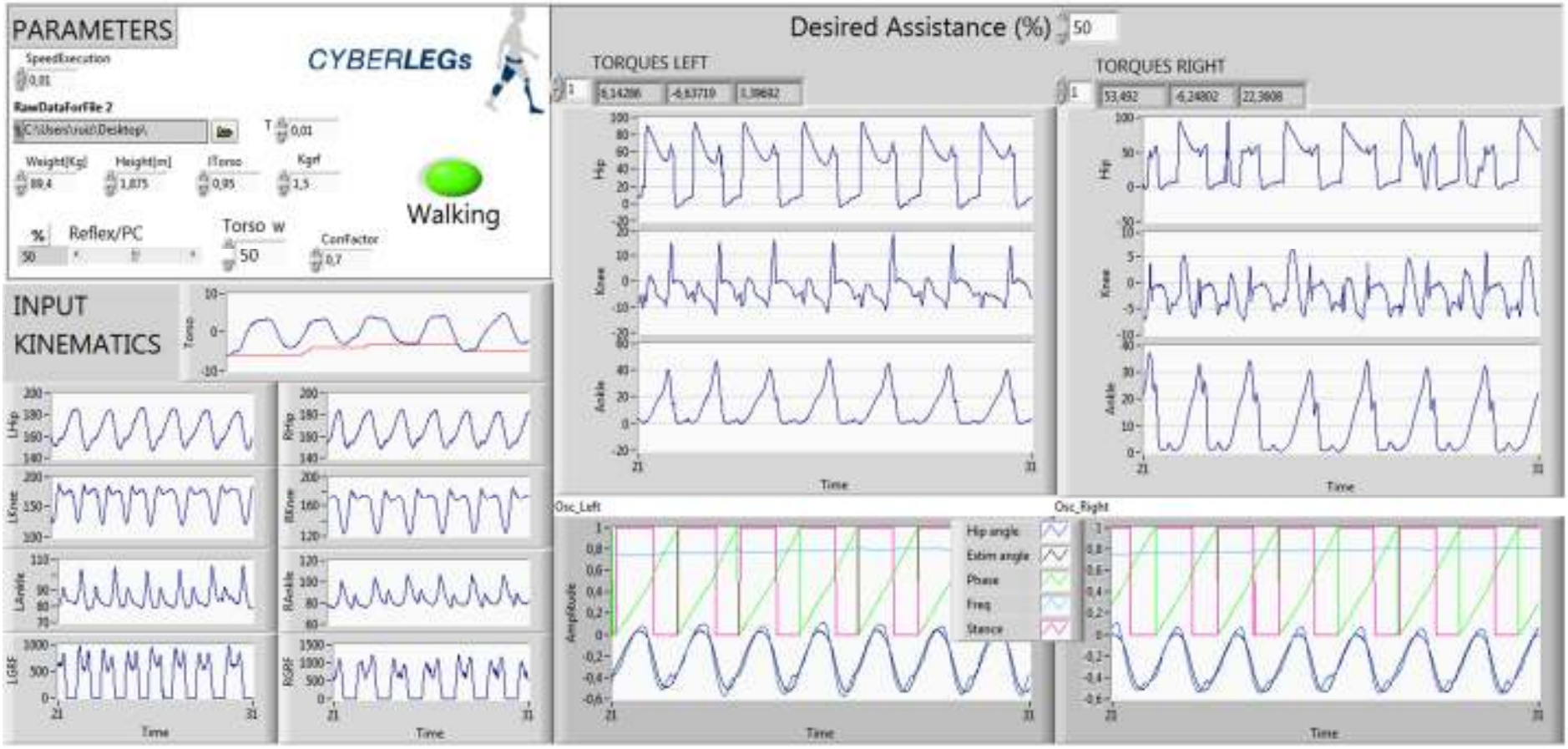
- Hip Orthosis (SSSA)



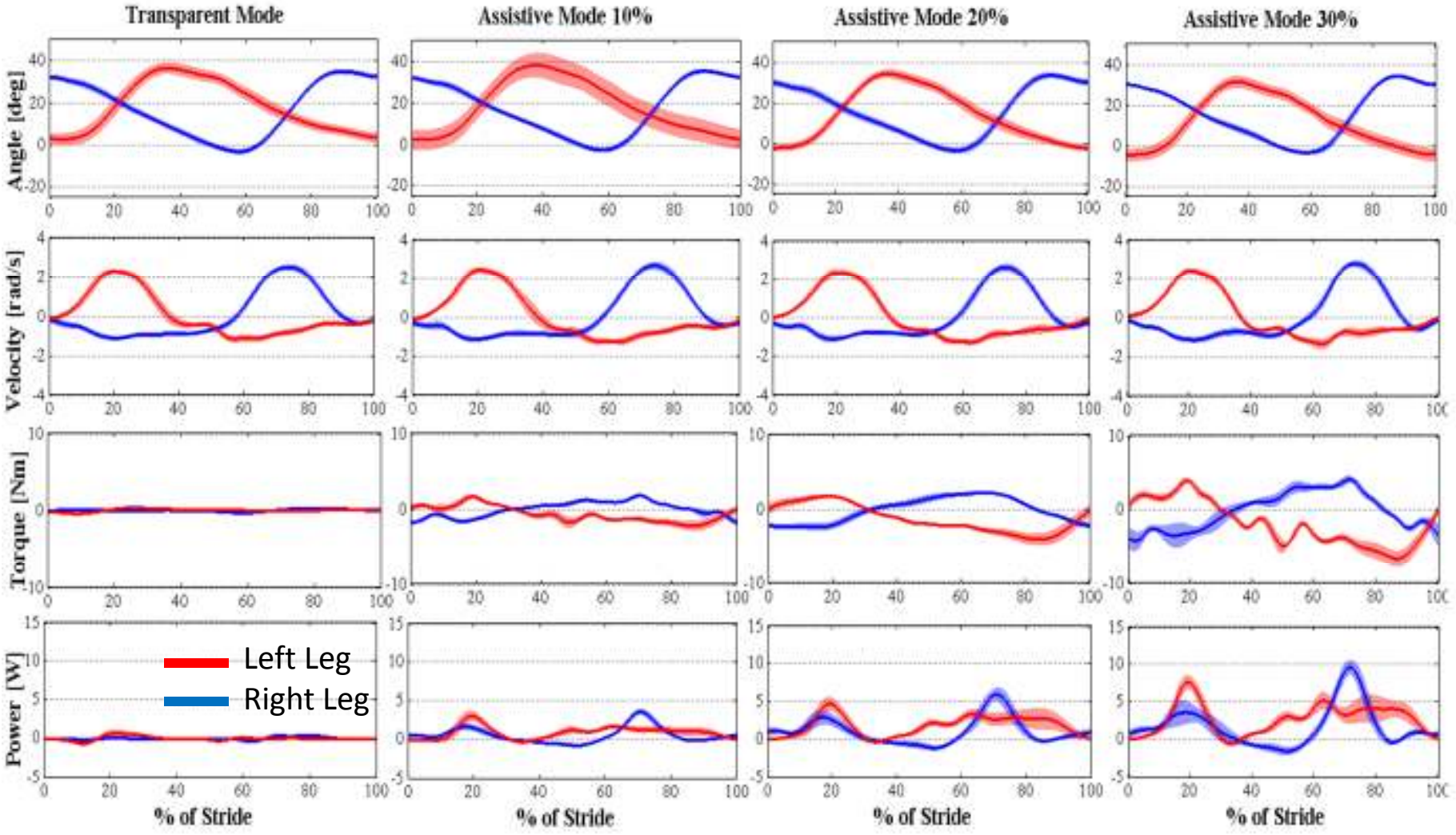
- Wearable Sensory Apparatus & Sensorized Insoles (UL, SSSA)



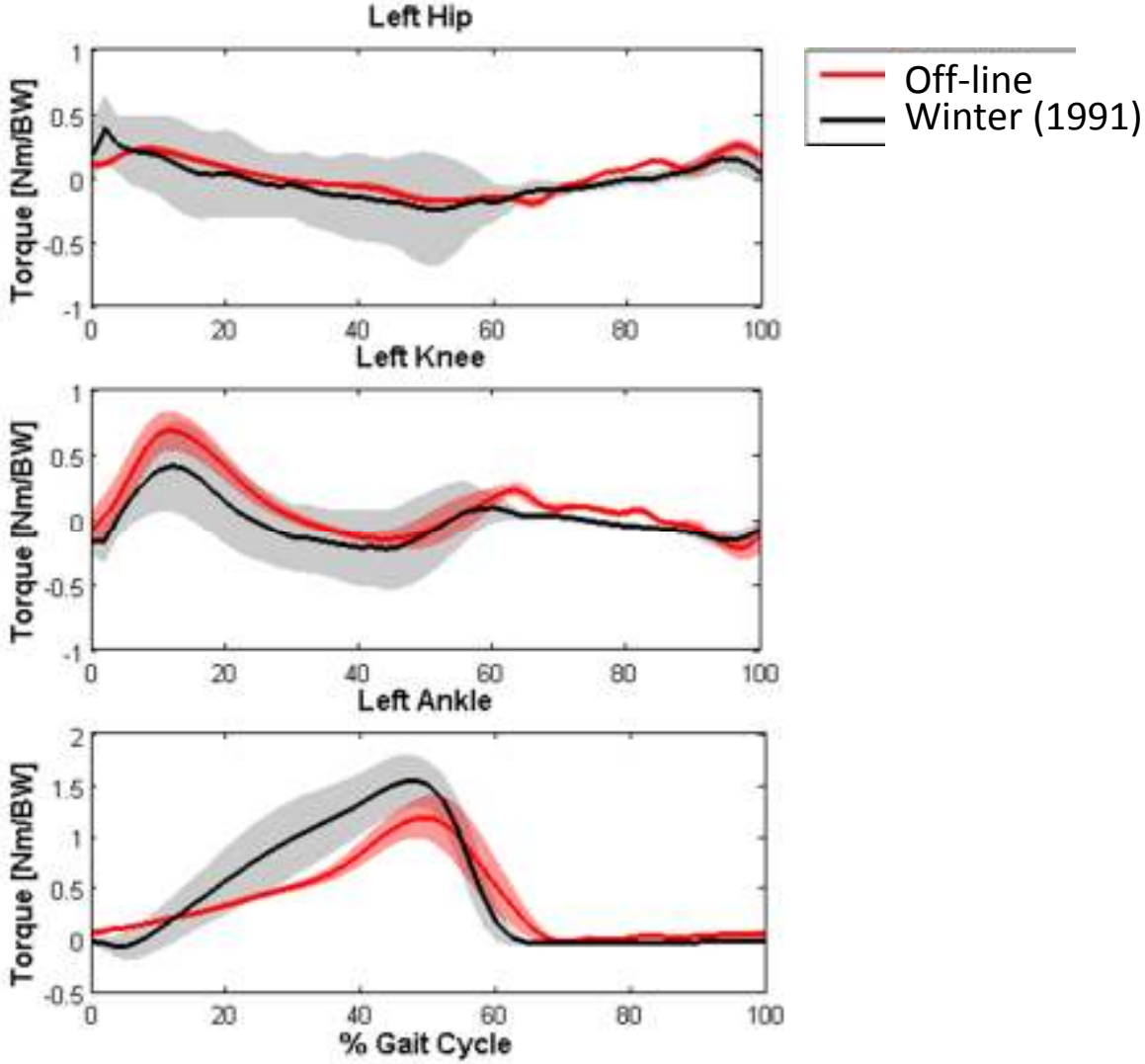
Real Time


PARAMETERS
CYBERLEGs
Walking
Reflex/PC
Torso w
50
Confactor
INPUT
KINEMATICS
Desired Assistance (%)
50
TORQUES LEFT
TORQUES RIGHT
Hip
Knee
Ankle
Time
Osc_Left
Osc_Right
Hip angle
Estim angle
Phase
Freq
Stance

Subject 2. Only FF+ wTB=2Hz



30% Assistance



Outline

- Conclusions and on-going work

- Bio-inspired assistive control model
- Real time assistance
- Further work:
  - Optimization of model parameters
  - Reflex adaptation for stairs
  - Experiments
    - Usefulness of Muscle layer
    - Assess comfort and assistive capability
    - Find the best combination from the stimulation sources

THANK YOU