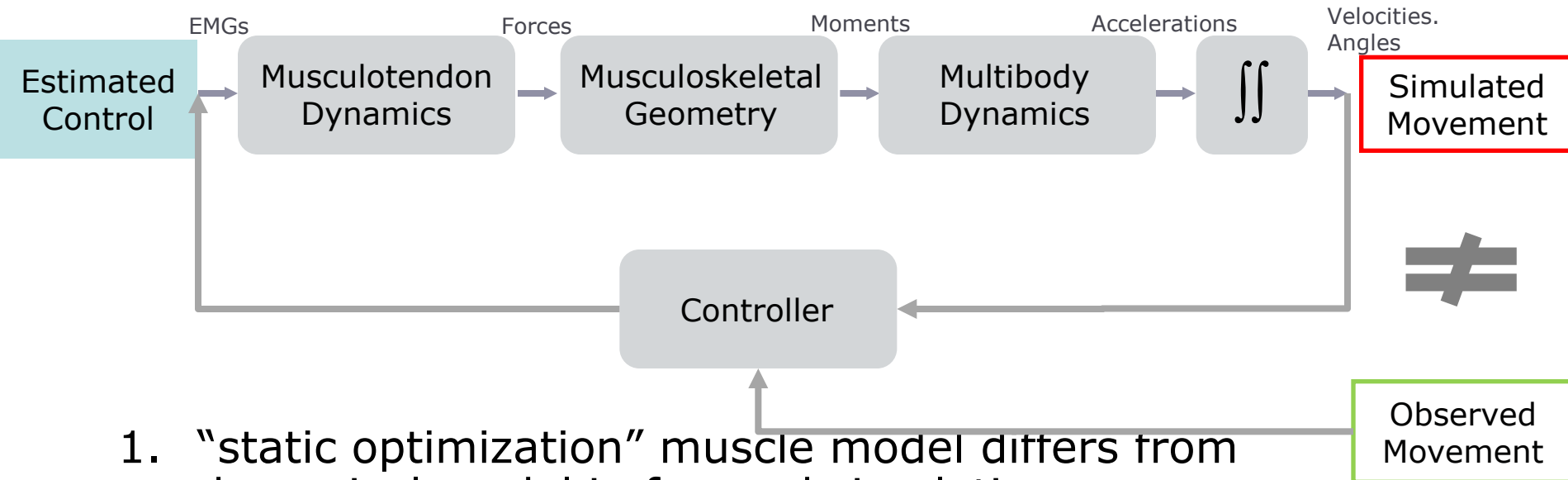




## Behind Computed Muscle Control

# Muscle-Driven Forward Simulation

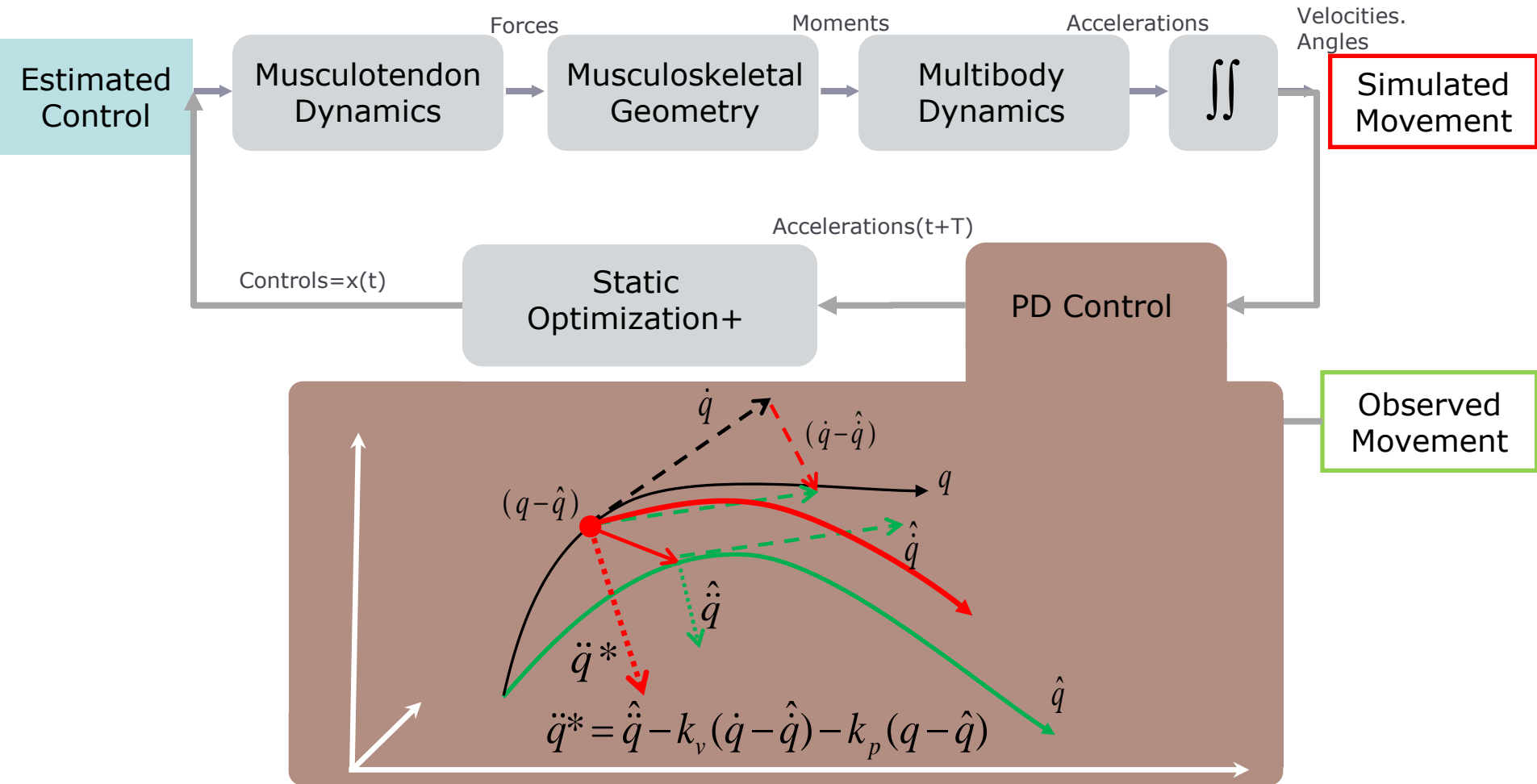


1. “static optimization” muscle model differs from dynamical model in forward simulation.

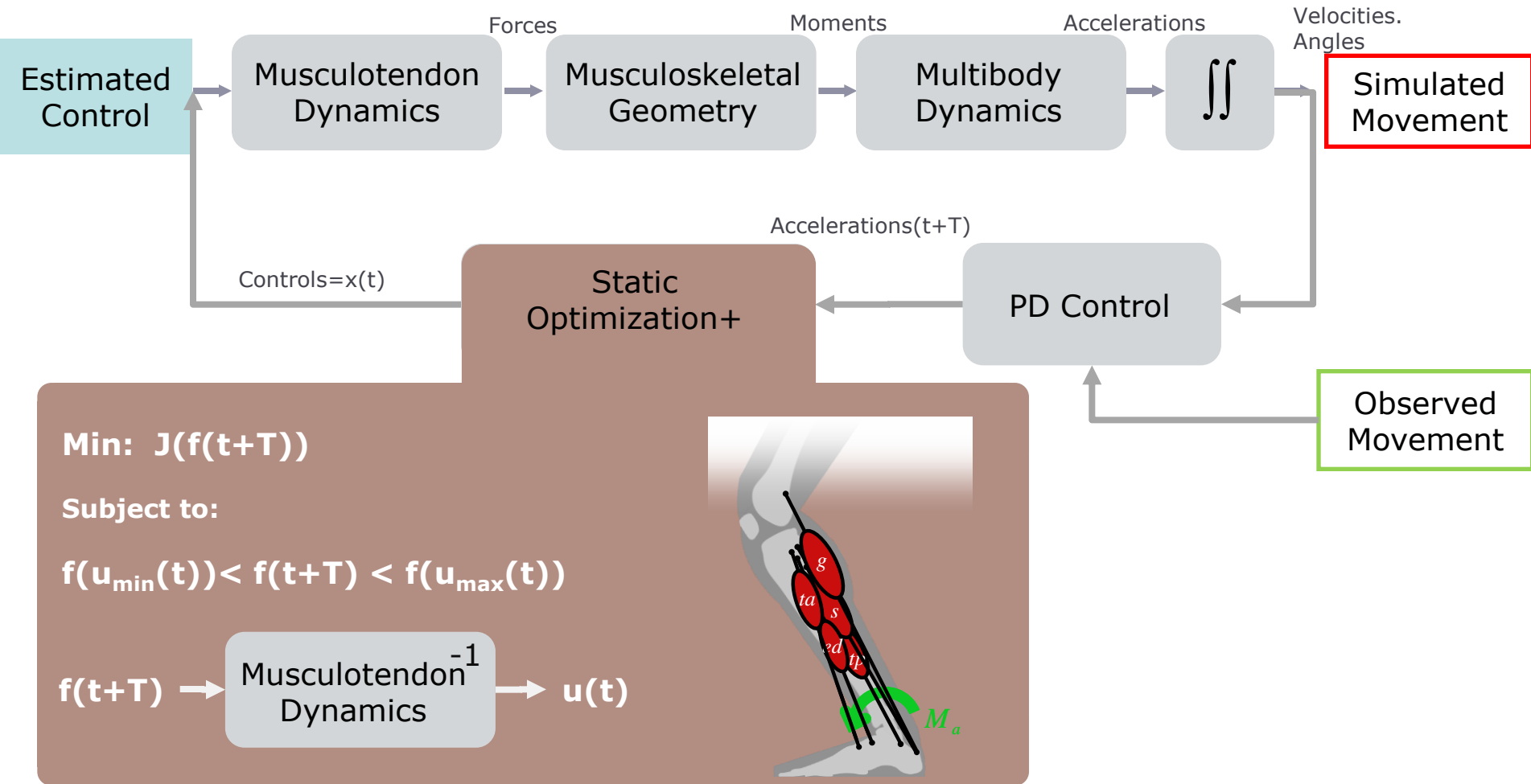
2. Acceleration data is discrete and noisy.

3. Numerical integration.

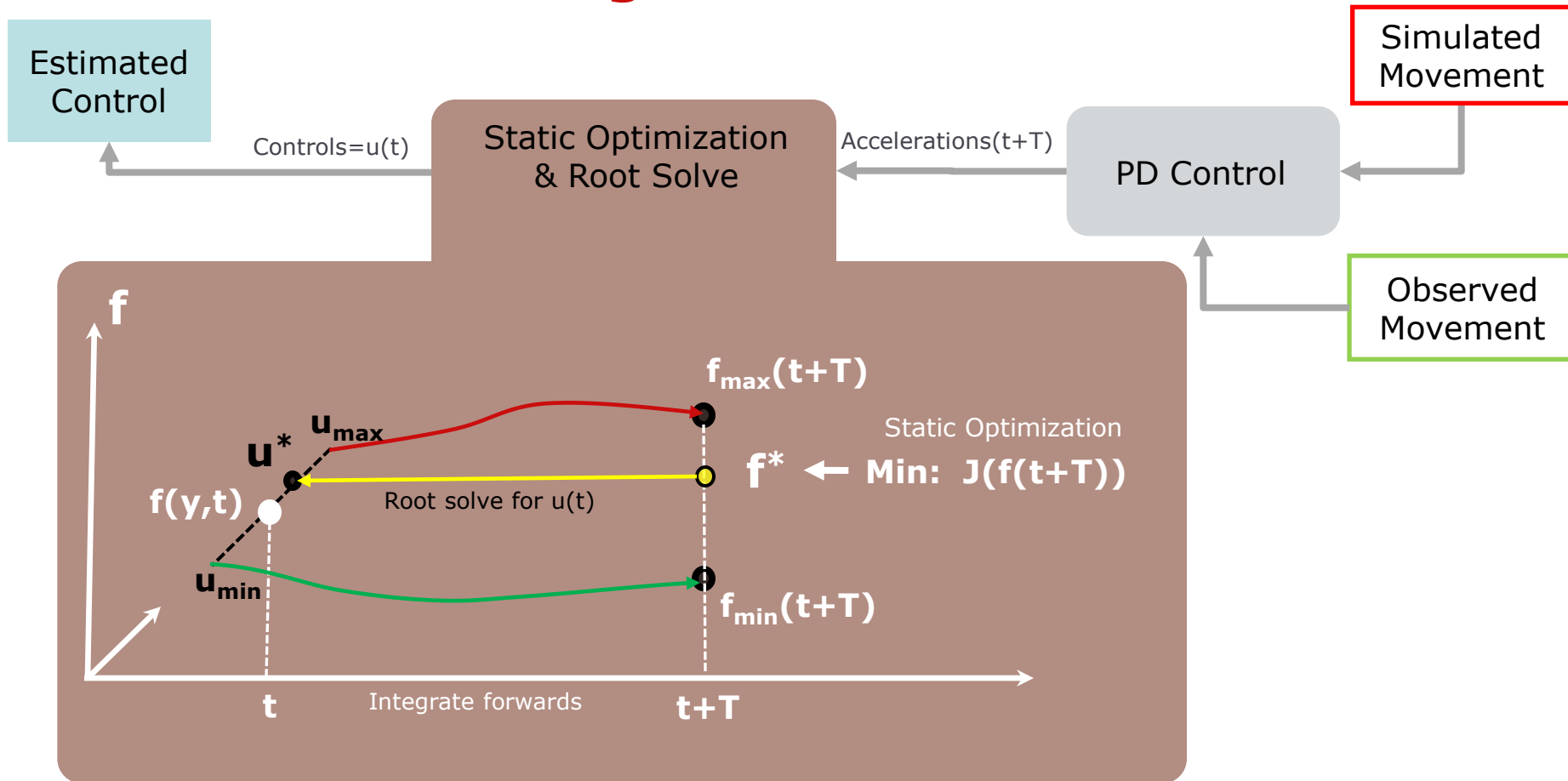
# Computed Muscle Control (CMC)



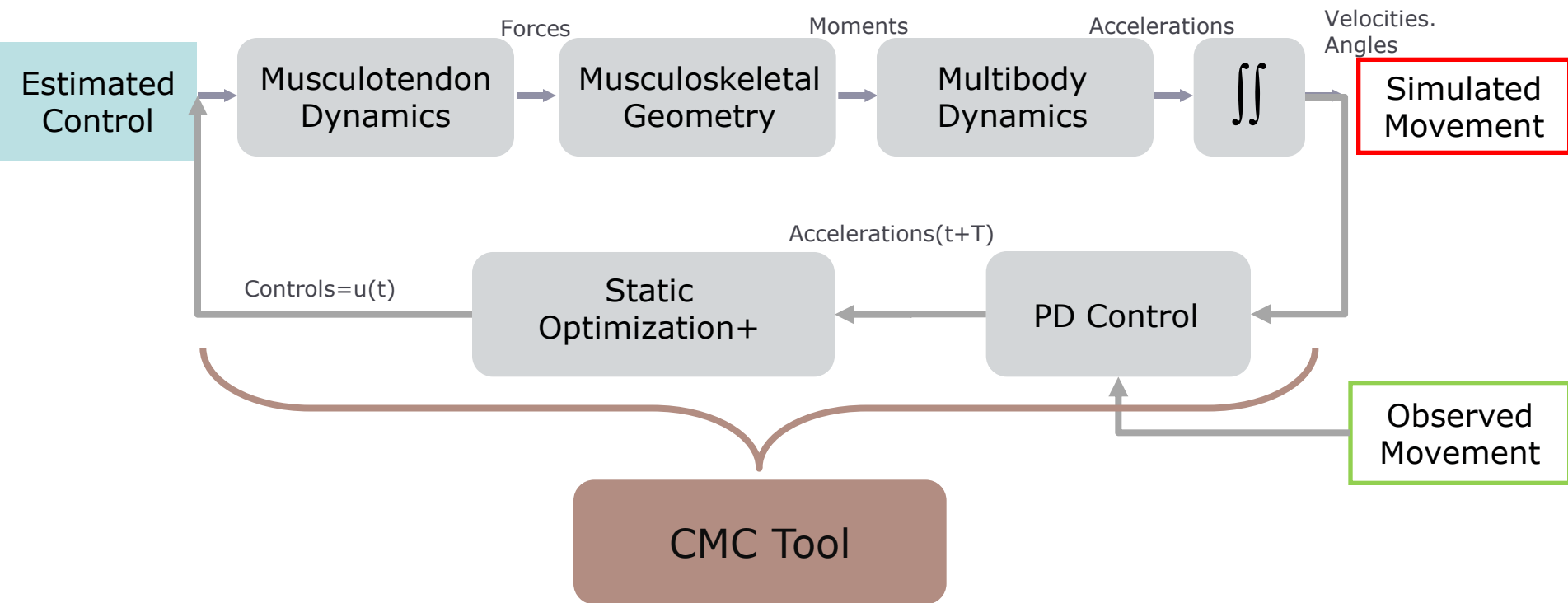
# Computed Muscle Control (CMC)



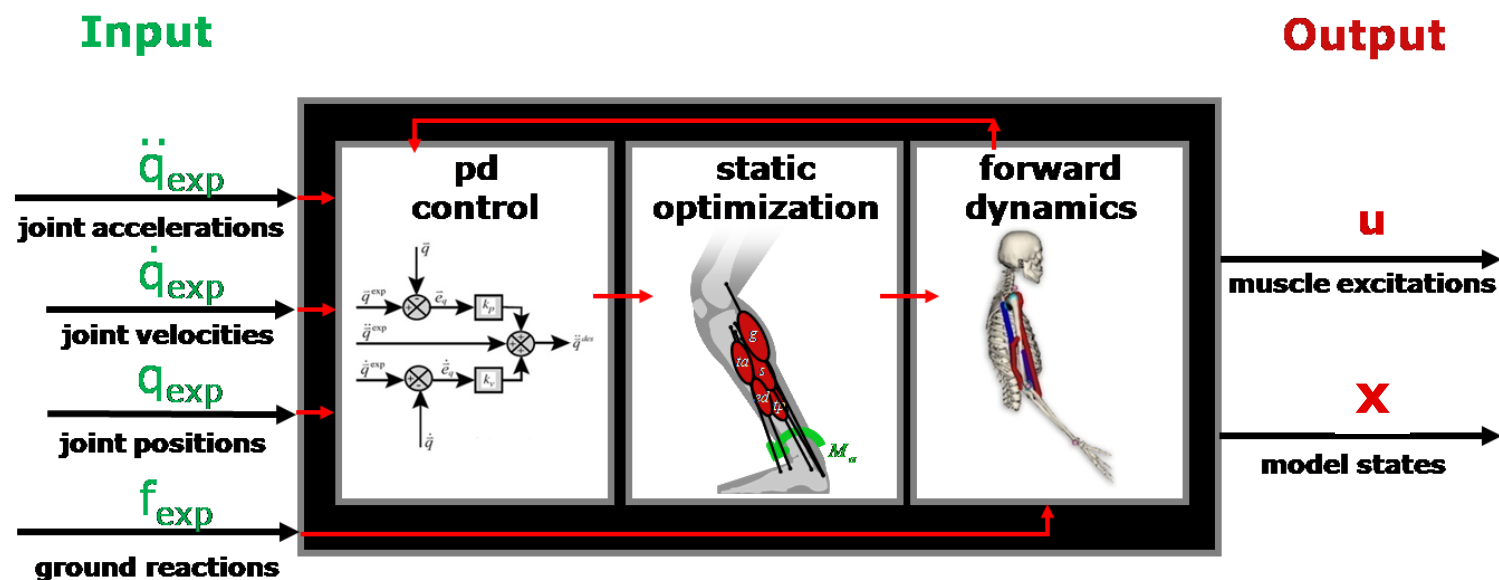
# Inside the CMC Algorithm



# Computed Muscle Control Tool:



# Computed Muscle Control



## TIPS & TRICKS

You can use results from IK or RRA. For best results, track RRA output not IK.

Increase max excitation of reserves if CMC is failing.

Compare to EMG and constrain excitations where there is a mismatch.

Command Line: `cmc -S cmc_setup_file.xml`

# Our Experience with Computed Muscle Control

Use CMC to generate inputs for a forward simulation that tracks experimental data.

CMC does not globally optimize cost function.



Solution is sensitive to initial time simulation.

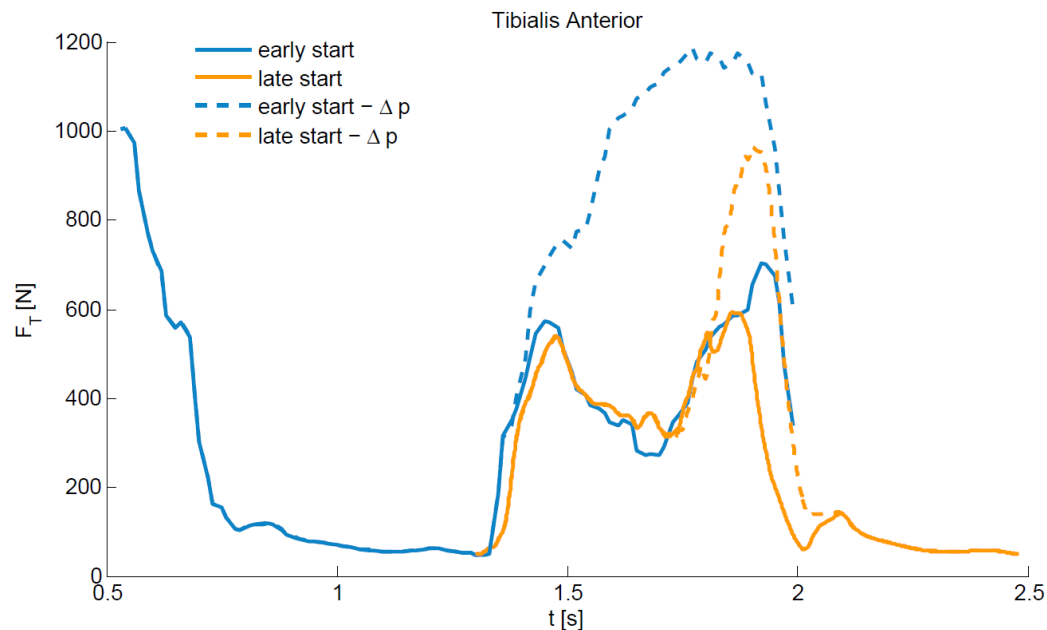
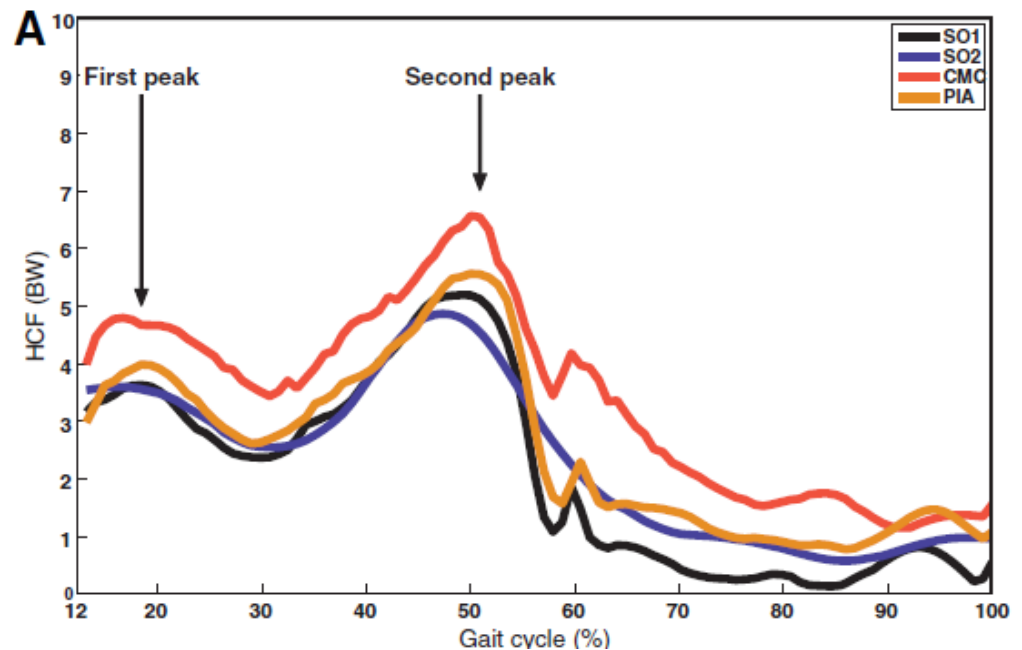
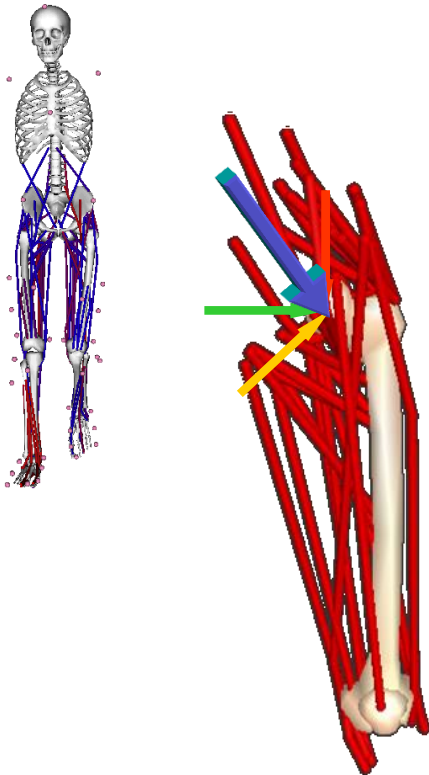


Figure from Wesseling (2014), J Biomech 47: 596–601



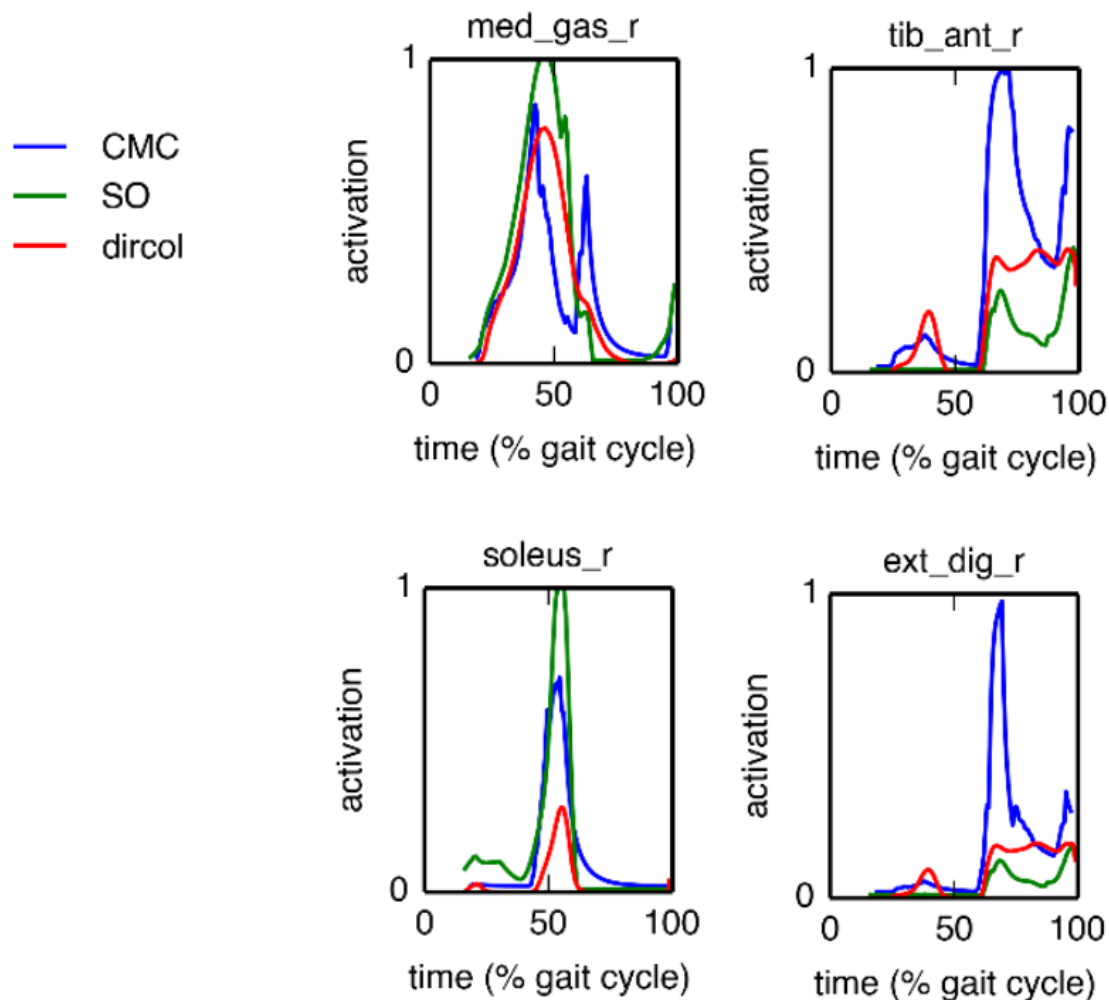
# Our Experience with Computed Muscle Control

Use CMC to generate inputs for a forward simulation that tracks experimental data.



From Wesseling et al., J. Orthop. Res., 2015

# Comparing SO and CMC



- Accounting for muscle dynamics results in smaller muscle activations for muscles with long tendons. Increased efficiency due to energy storage and release in compliant tendons.
- Optimizing performance over complete motion results in further reduction of muscle forces. Anticipate instead of correct.

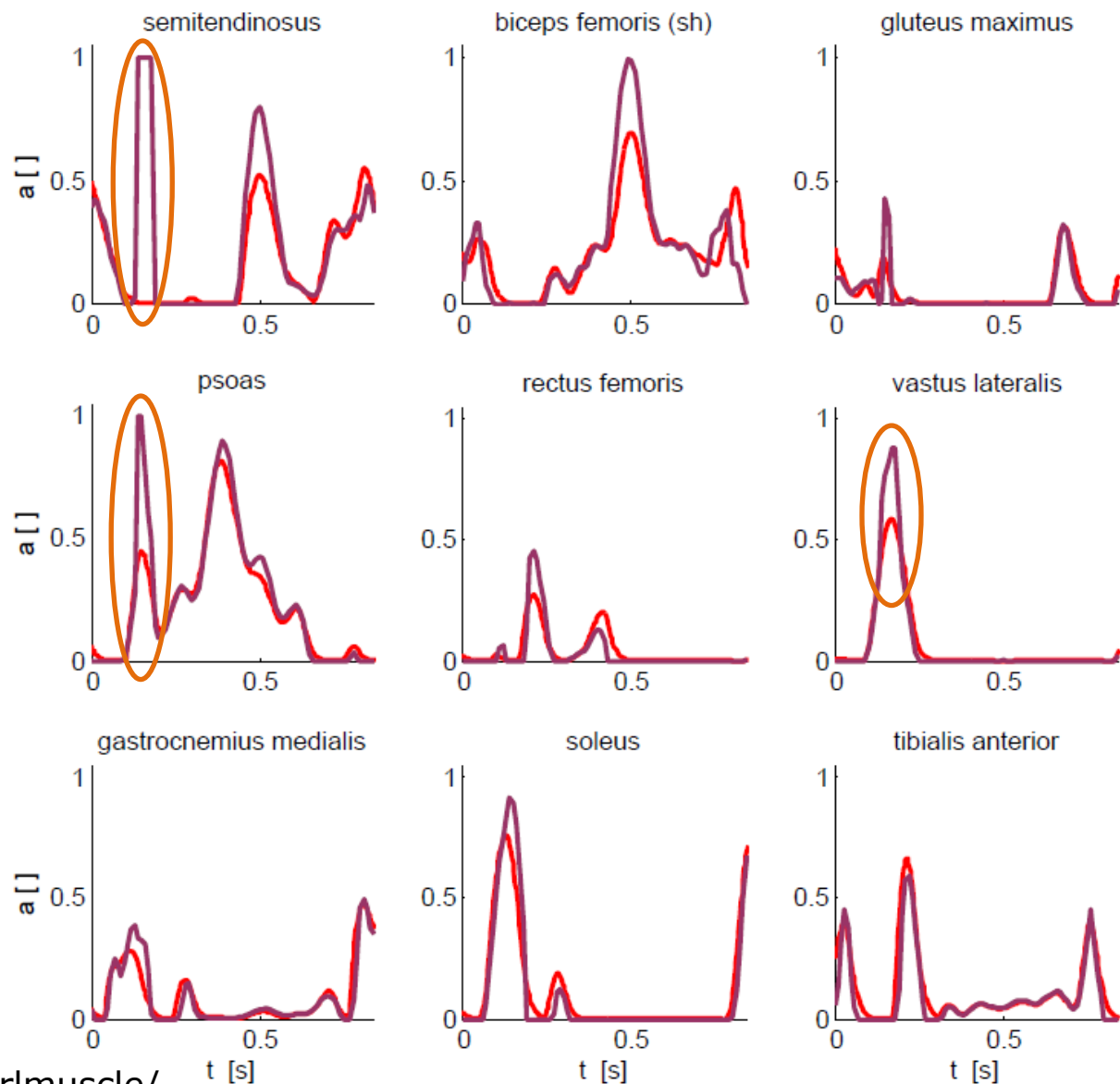
Dynamic optimization code @ <https://simtk.org/projects/optcntrlmuscle/>

# Comparing Static and Dynamic Optimization

## RUNNING

Muscle dynamics increases performance during running.

— static optimization  
— dynamic optimization



## Demo

C:\OpenSim 3.3\Models\Gait2392\_Simbody\

Evaluating your results:

- See table.
- Compare simulated activations to experimental EMG data (either recorded from your subject or from the literature)

Thresholds:	GOOD	OKAY	BAD
MAX Residual Force (N)	0-10 N	10-25N	> 25 N
RMS Residual Force (N)	0-10 N	10-25 N	> 25 N
MAX Residual Moment (Nm)	0-50 Nm	50-75 Nm	>75 Nm
RMS Residual Moment (Nm)	0-30 Nm	30-50 Nm	>50 Nm
MAX pErr (trans, cm)	0-1 cm	1-2 cm	>2 cm
RMS pErr (trans, cm)	0-1 cm	1-2 cm	>2 cm
MAX pErr (rot, deg)	0-2 deg	2-5 deg	> 5 deg
RMS pErr (rot, deg)	0-2 deg	2-5 deg	> 5 deg
MAX Reserve (Nm)	0-25 Nm	25-50 Nm	> 50 Nm
RMS Reserve (Nm)	0-10 Nm	10-25 Nm	> 25 Nm