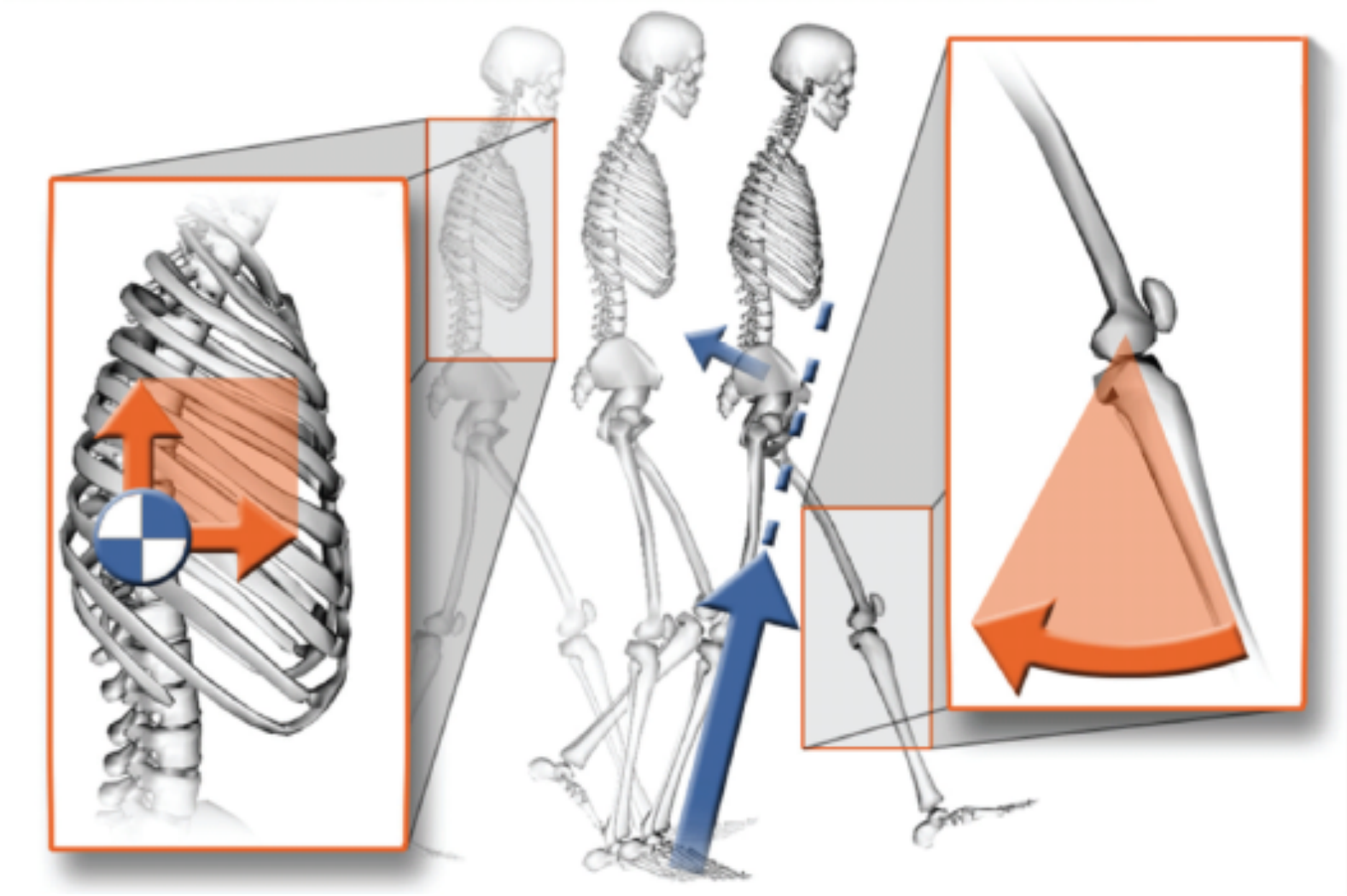
Agenda

8:30 – 9:00	Welcome and Workshop Goals *Scott Delp and Jen Hicks*
9:00 – 10:15	Participant Introduction and Goals
10:15 – 10:30	Break
10:30 – 12:00	**Generating Forward Simulations with RRA and CMC** ***Ajay Seth and Sam Hamner***
12:00 – 1:00	Lunch
1:00 – 2:00	Components of an OpenSim Model and Model Editing *Matt Demers*
2:00 – 2:15	Break
2:15 – 2:30	Solidify Project Plans
2:30– 5:00	Work on Projects



Reducing Residuals

What are residuals?

Non-physical forces that account for inconsistencies between experimental GRFs and joint accelerations estimated from experimental markers.

$$F = ma + R$$

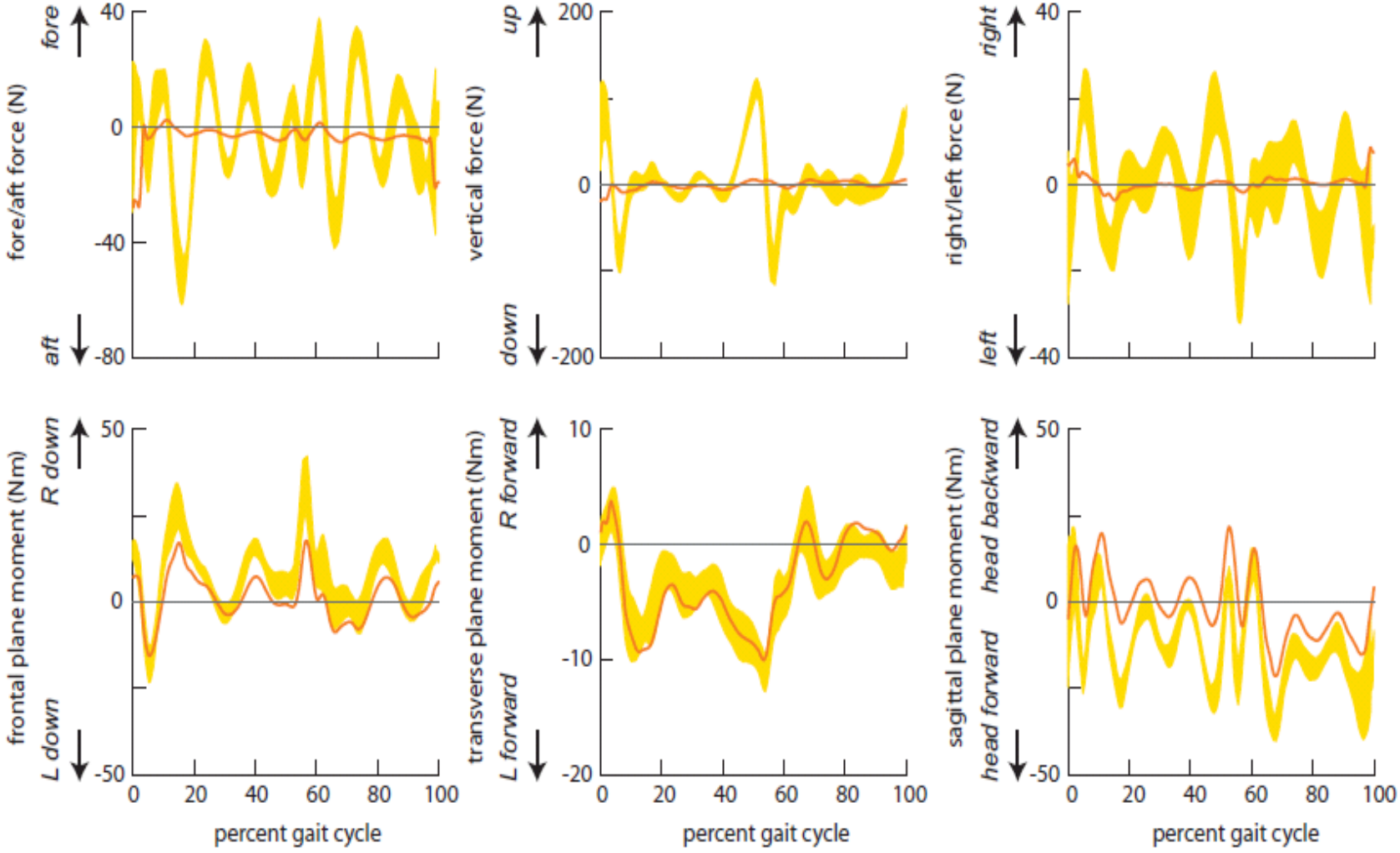
Inconsistencies due to:

1. noise in marker and joint angle data
   - differentiating angles for accelerations
2. inaccuracies in model geometry and mass distribution

Why reduce residuals?

1. Residuals are non-physical and necessary only to account for errors
2. Want muscles to account for all movement
3. To have confidence in muscle contributions

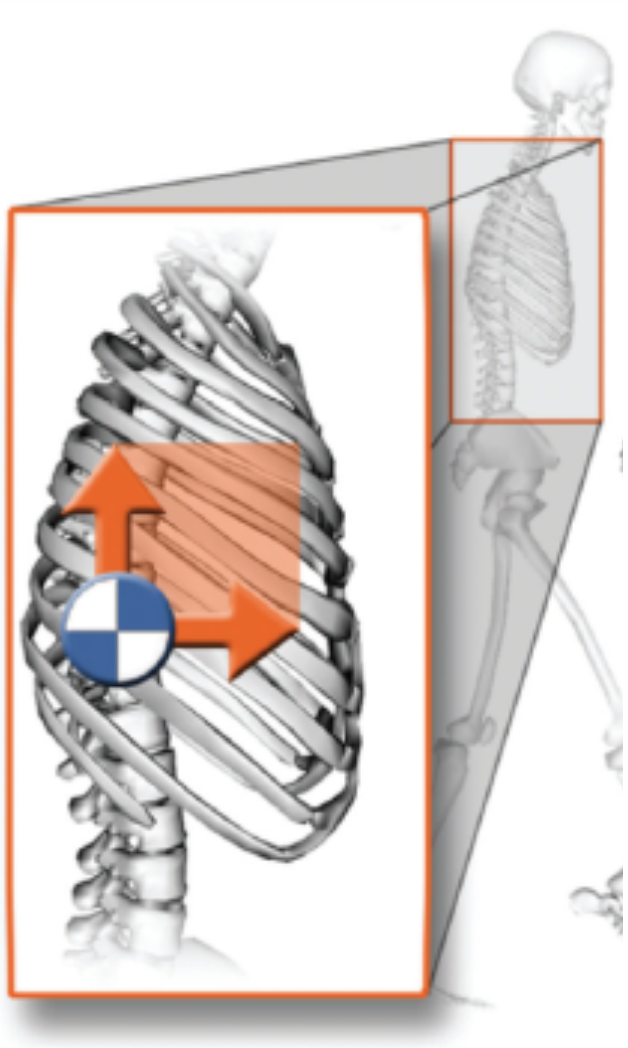
Sample residual reduction during gait



How can you reduce residuals?

- Torso is most massive and error prone to estimate
- Location of Torso mass center also difficult to estimate

1. Adjust mass distribution including Torso COM location



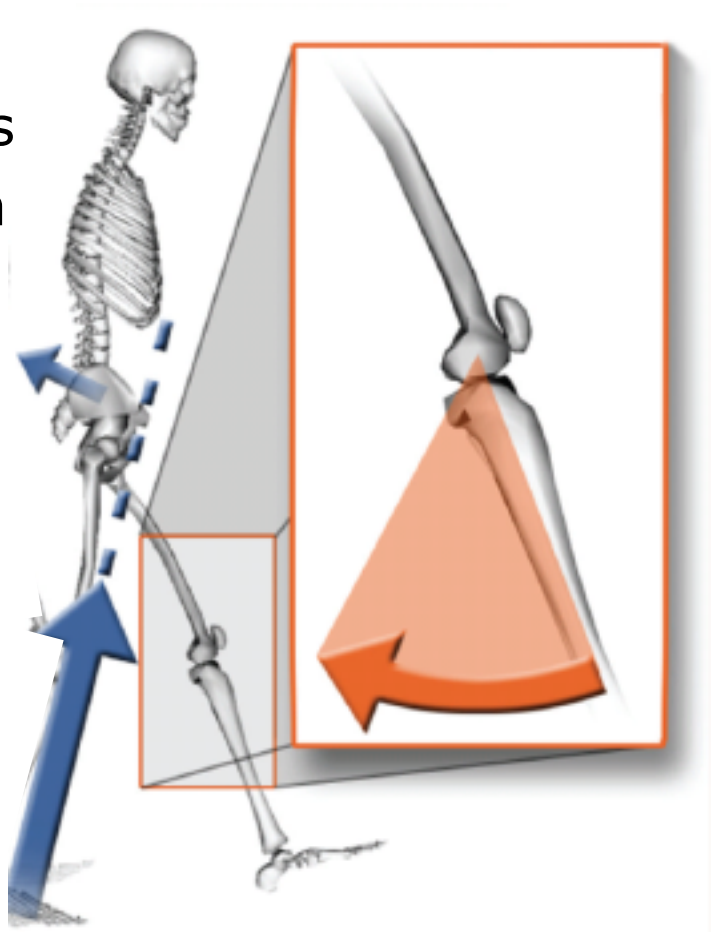
How can you reduce residuals?

- Joint kinematics estimated from marker position has inaccuracies
- Differentiation of kinematics can yield non-physical accelerations

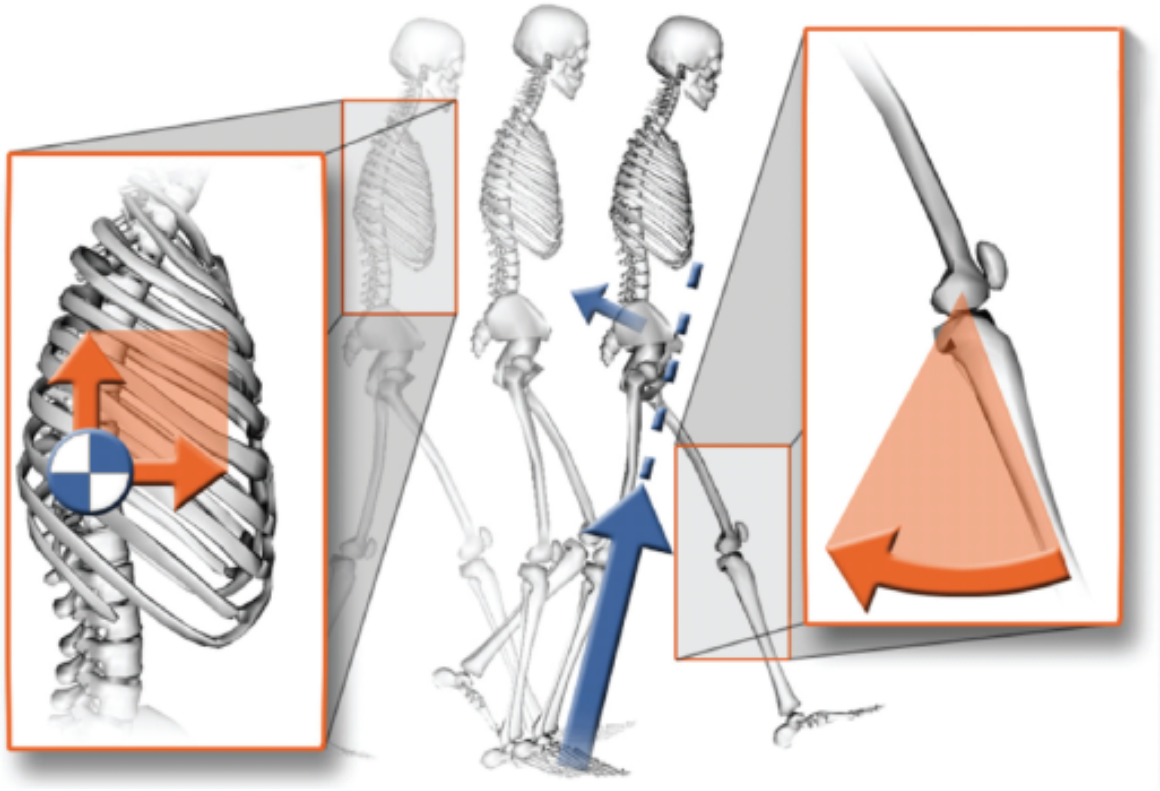
1. Adjust mass distribution including Torso COM location

2. Adjust kinematics slightly while satisfying equations of motion

RRA tracks kinematics in a forward dynamics simulation



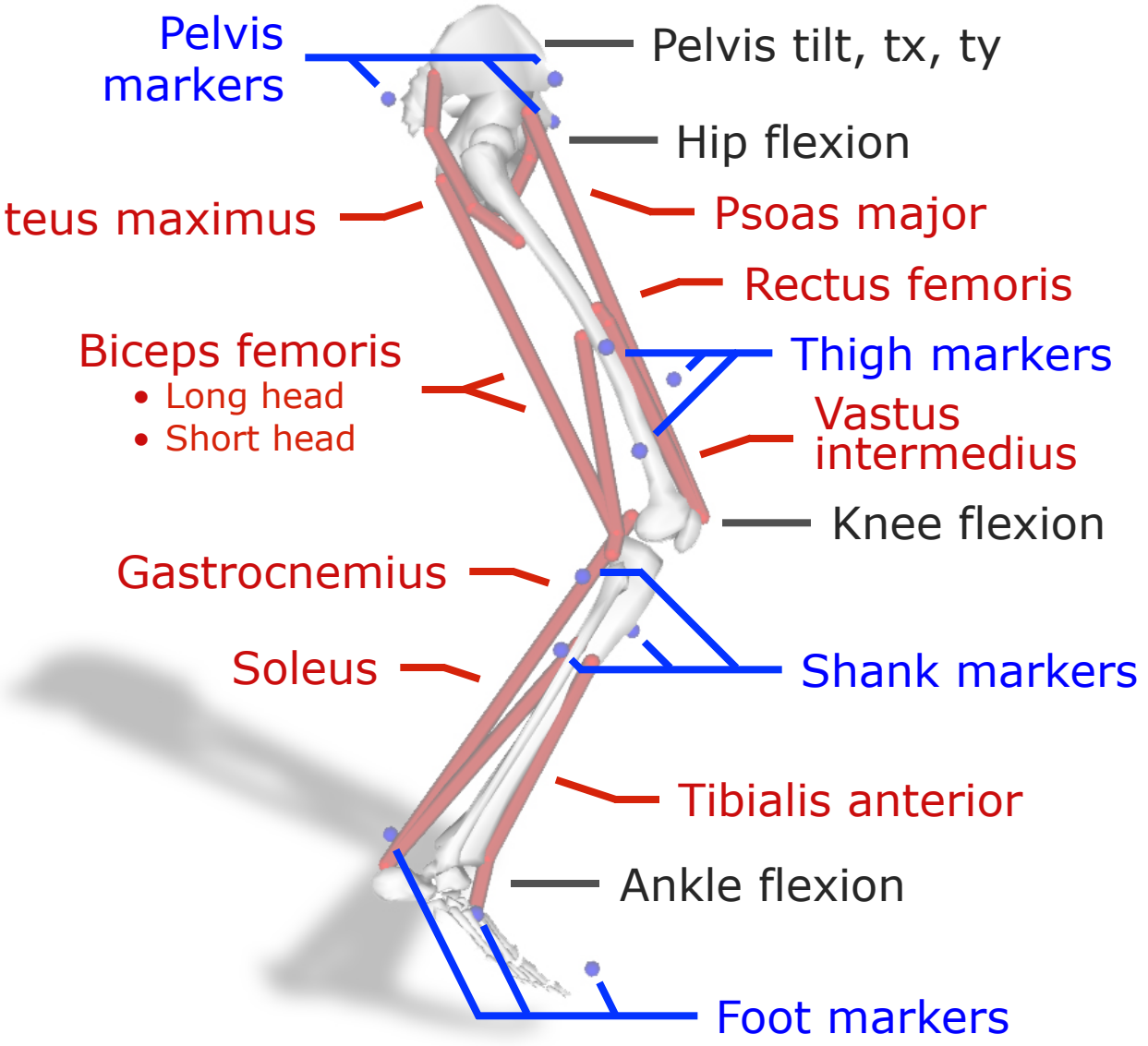
Residual Reduction Algorithm (RRA)



TIPS & TRICKS
Keep optimal forces for residuals low (increase control bounds if necessary)
Lower weight on kinematics that track closely or have low confidence in measurement
Make mass adjustments and run RRA again - repeat until residuals no longer change

Exercise: Forward Simulation of Stance

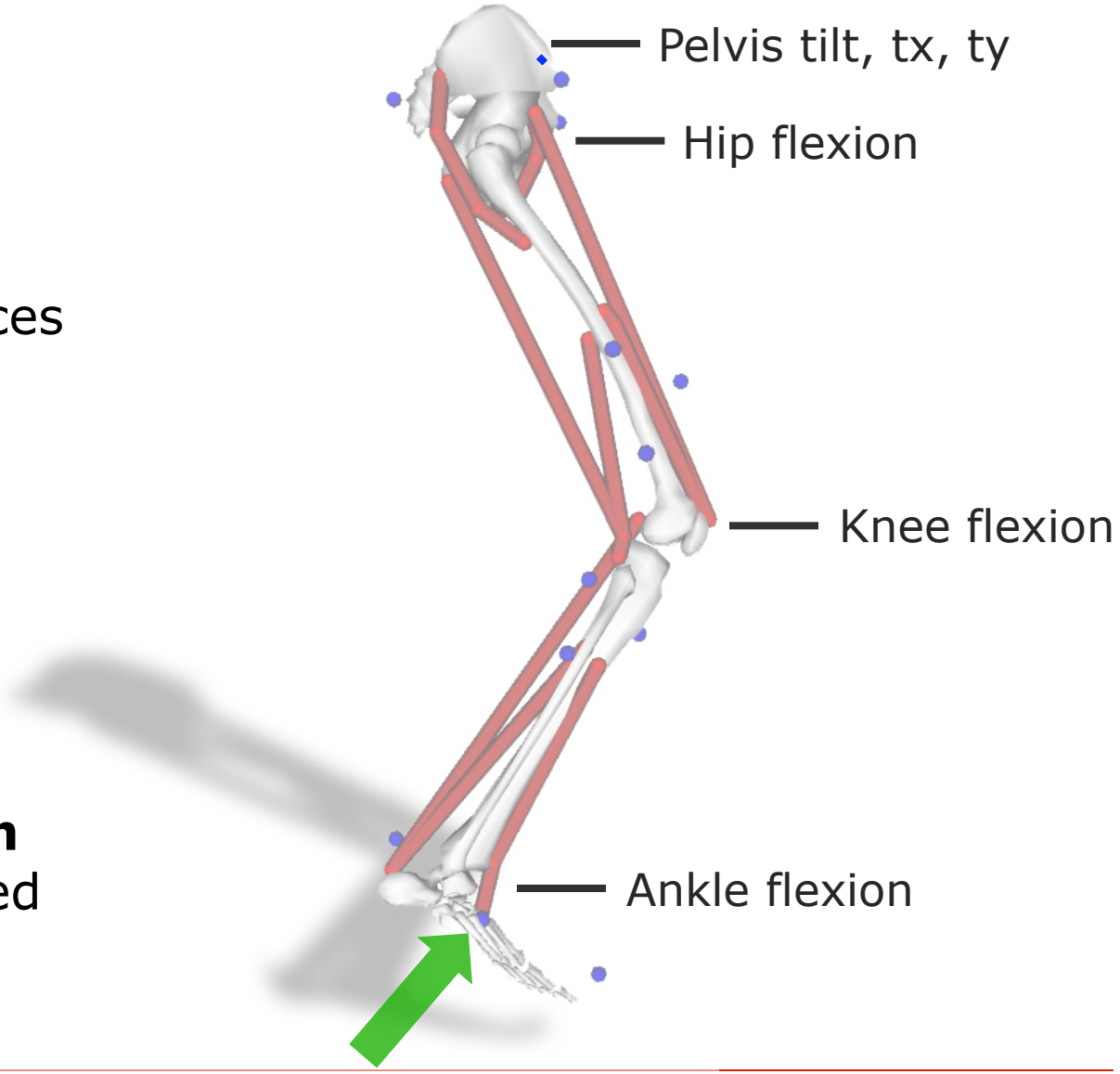
Leg Model:
6 Degrees of Freedom
9 Muscles



Part 1: Dynamically Consistent Model & Data

Leg Dynamics
3 Residual pelvis forces
3 Joint motors
GRF on foot

Launch OpenSim
Handout for detailed instructions



Work with your Group: Preliminaries and Inverse Dynamics

1. What type of data is available?

2. What time range were GRFs measured for the leg of interest?

3. Why are the residual forces so large?

4. Why is the vertical force the largest?

Work with your Group: Residual Reduction

1. Why does the model initially “float” up and down?

2. What process did you use to reduce residuals forces while maintaining good tracking?

3. What coordinates were most difficult to track?

4. How small is small enough for residual forces and tracking errors?

Part II: Muscle-driven Forward Simulation

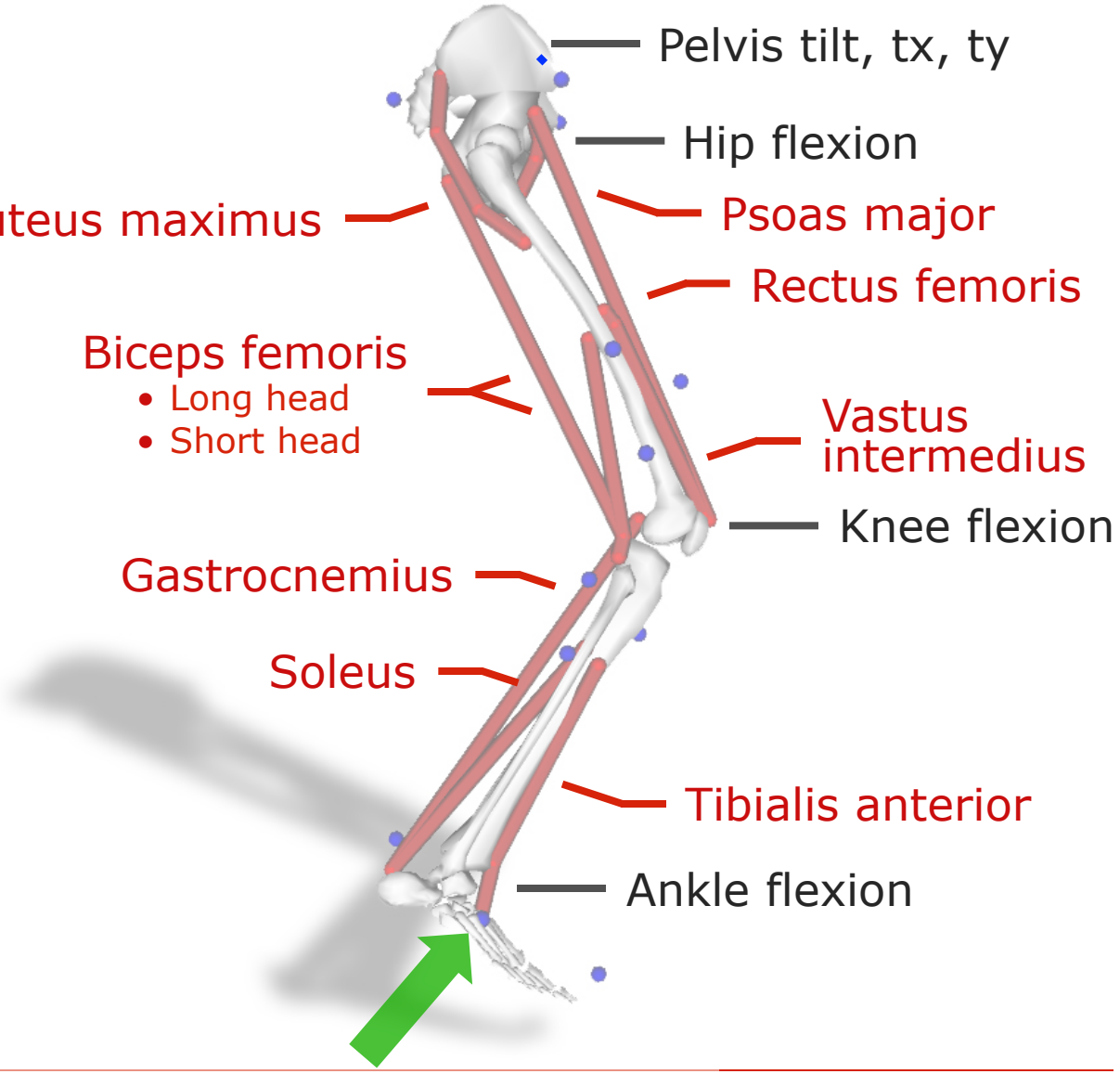
Leg Dynamics

3 Residual forces

3 Joint motors

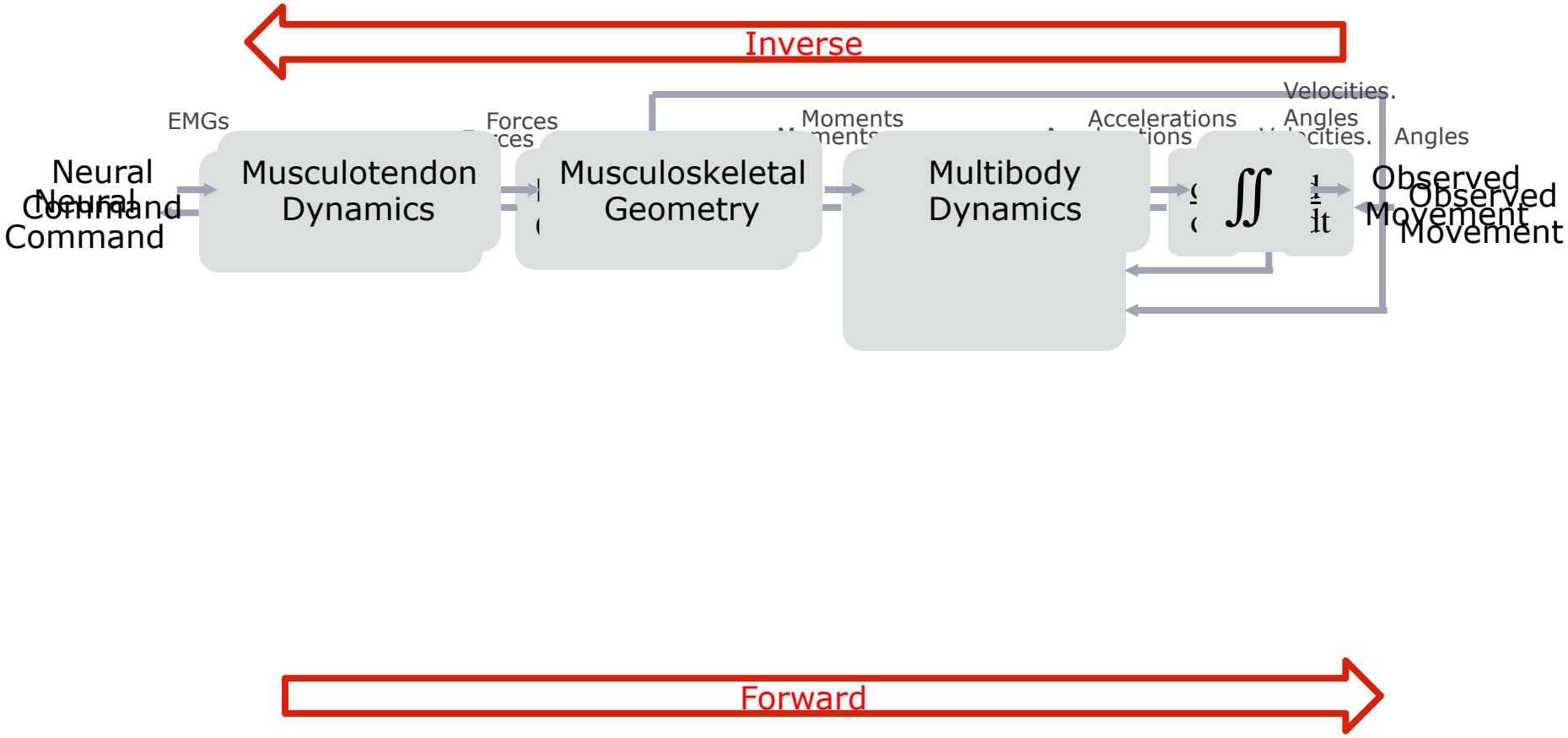
9 Muscles

GRF on the foot

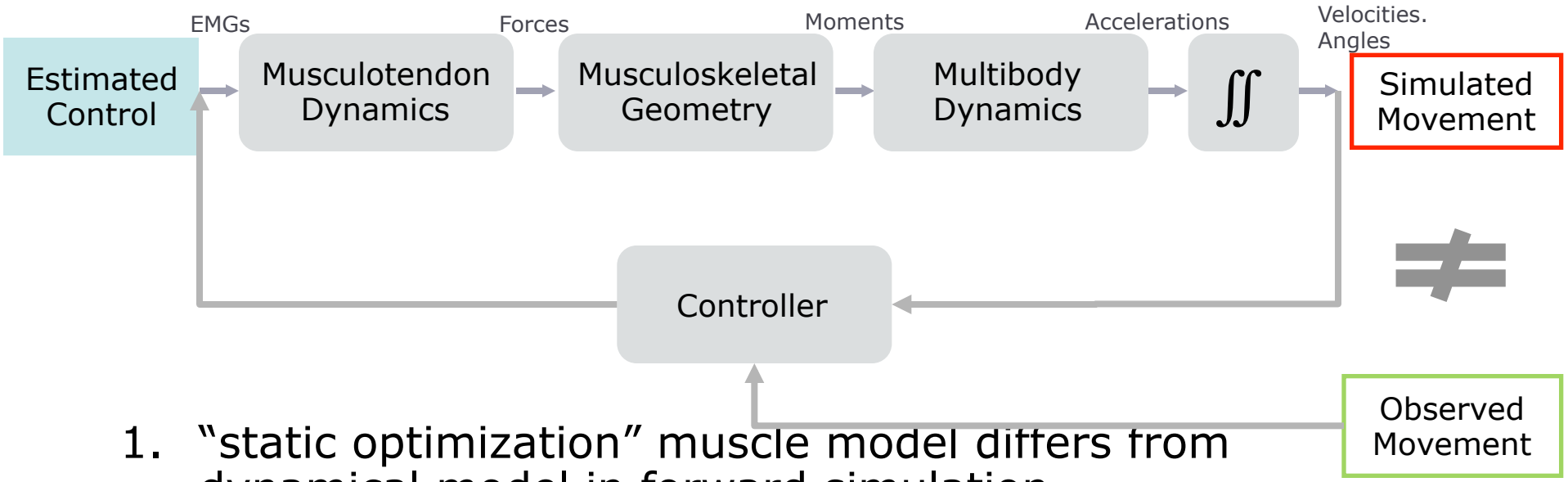


Behind Computed Muscle Control

Model Dynamics



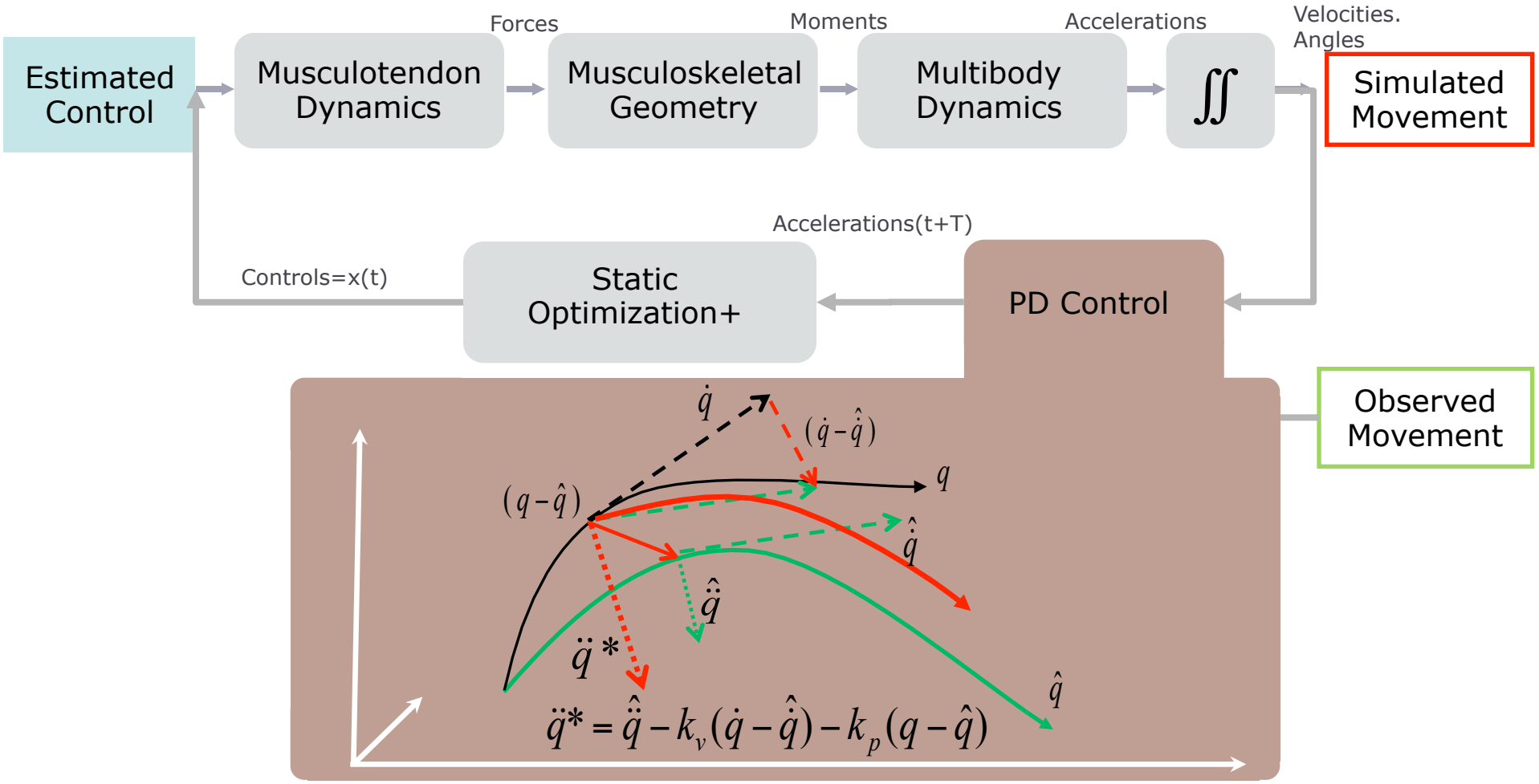
Muscle-Driven Forward Simulation



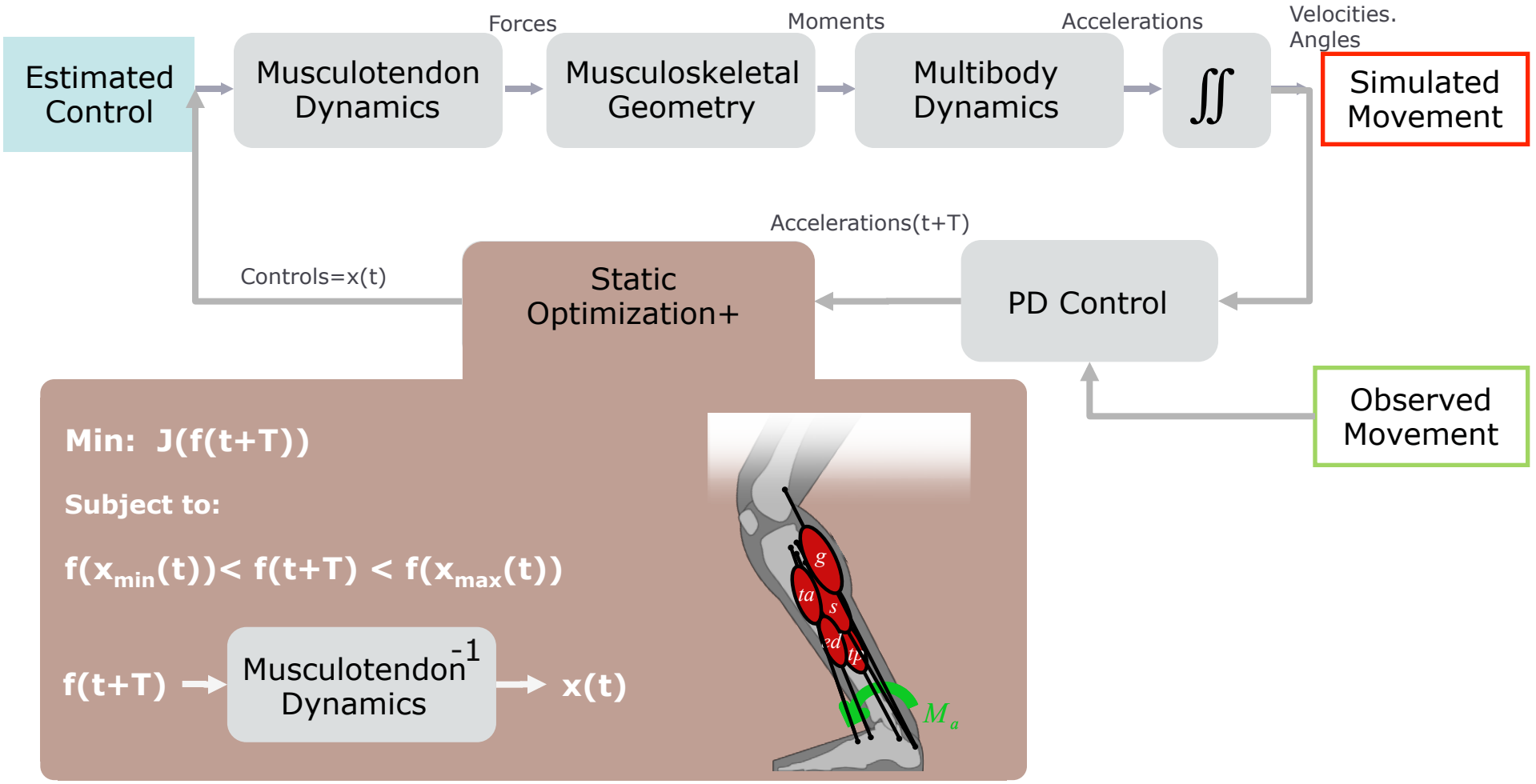
1. "static optimization" muscle model differs from dynamical model in forward simulation.
2. Acceleration data is discrete and noisy.
3. A nonlinear dynamical systems can be chaotic.

Solution: Close the loop!

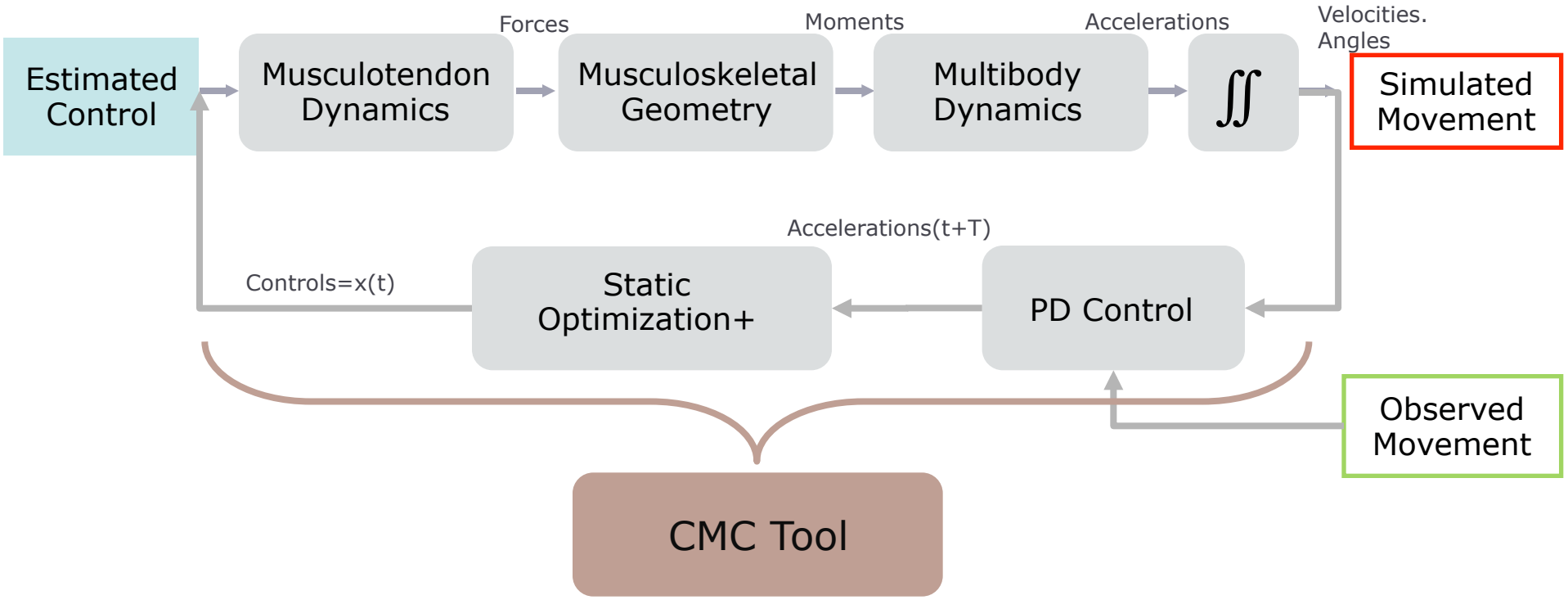
Computed Muscle Control (CMC)



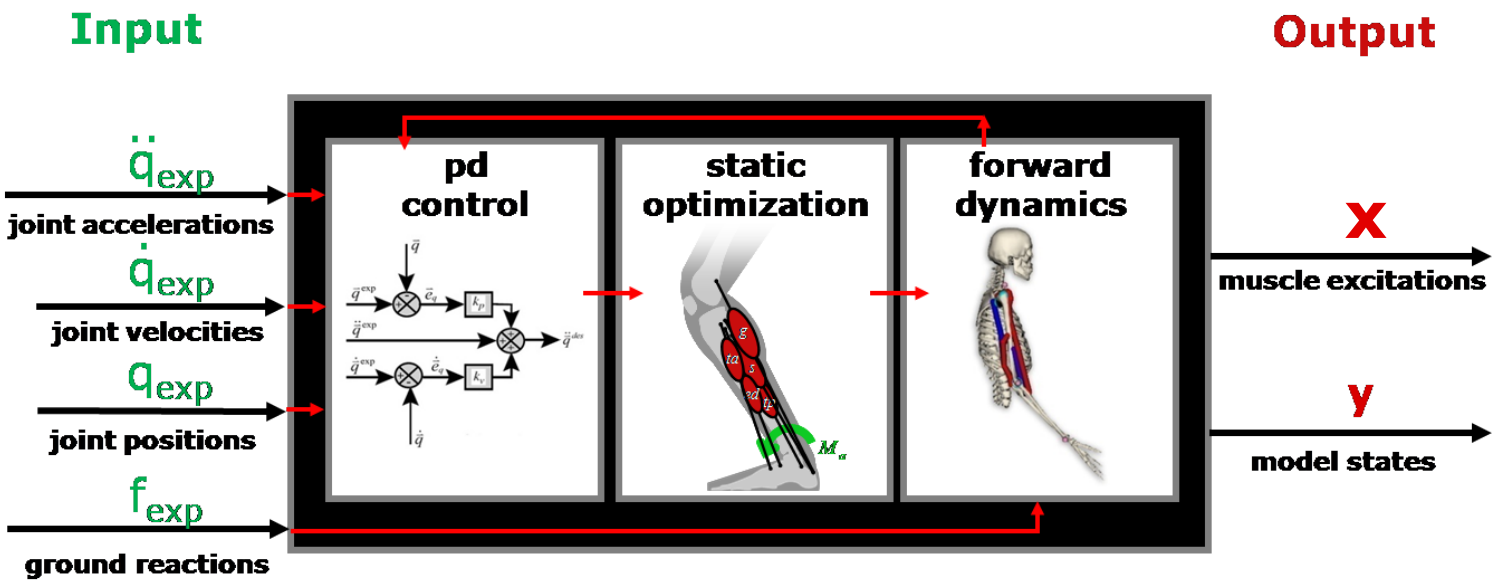
Computed Muscle Control (CMC)



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

Work with your Group: Computed Muscle Control

1. What is the difference between the actuator constraints file used in CMC and the file for RRA?

2. Plot the muscle activations, found in the states file. Are the observed activations close to what you expect?

3. How can you assess the quality of your simulation?

4. Are the residuals below 2% of body-weight?

5. Are the motor moments at the hip, knee and ankle significant?