Lecture 3

Systems-Level Modeling Overview

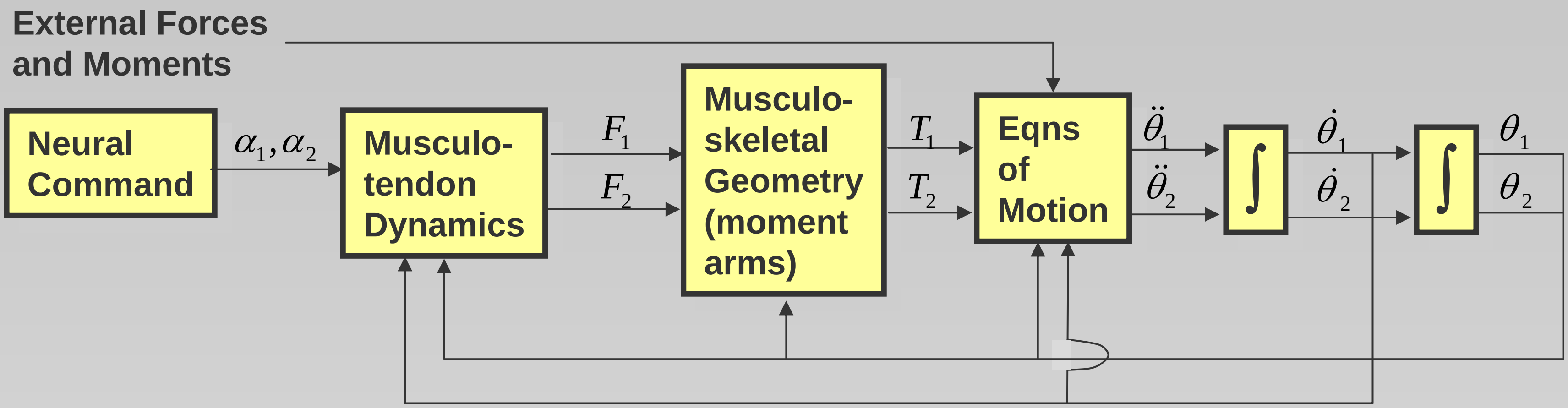
EML 5595

Mechanics of the Human Locomotor System

Outline

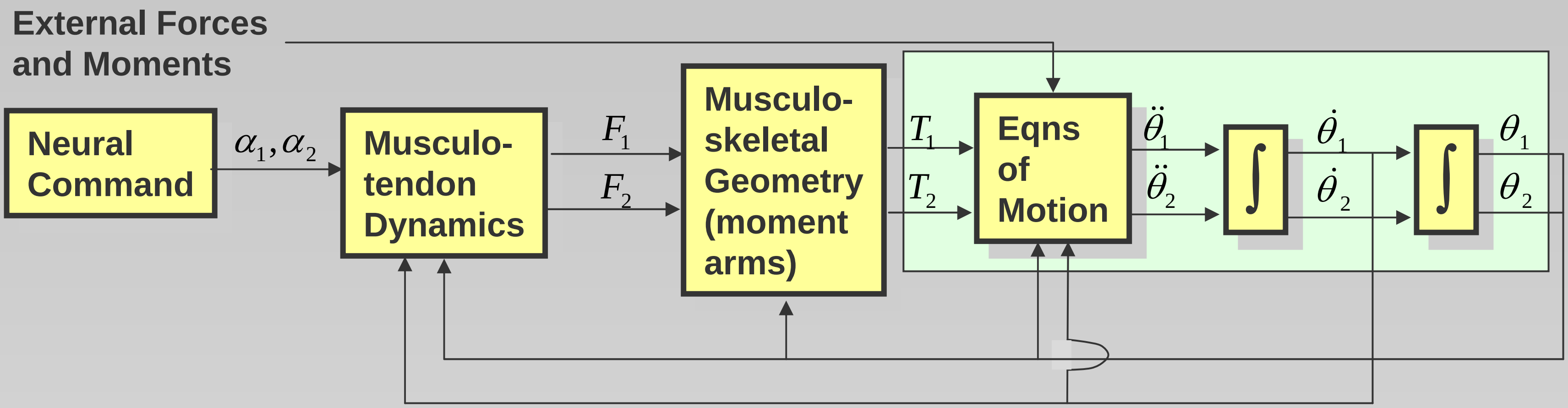
- Course Outline
- Journal Article Review Instructions
- Journal Article Review
  Zajac (1993)

Course Outline



1. Systems-level Modeling

Course Outline



1. Systems-level Modeling
2. Multi-joint Dynamics

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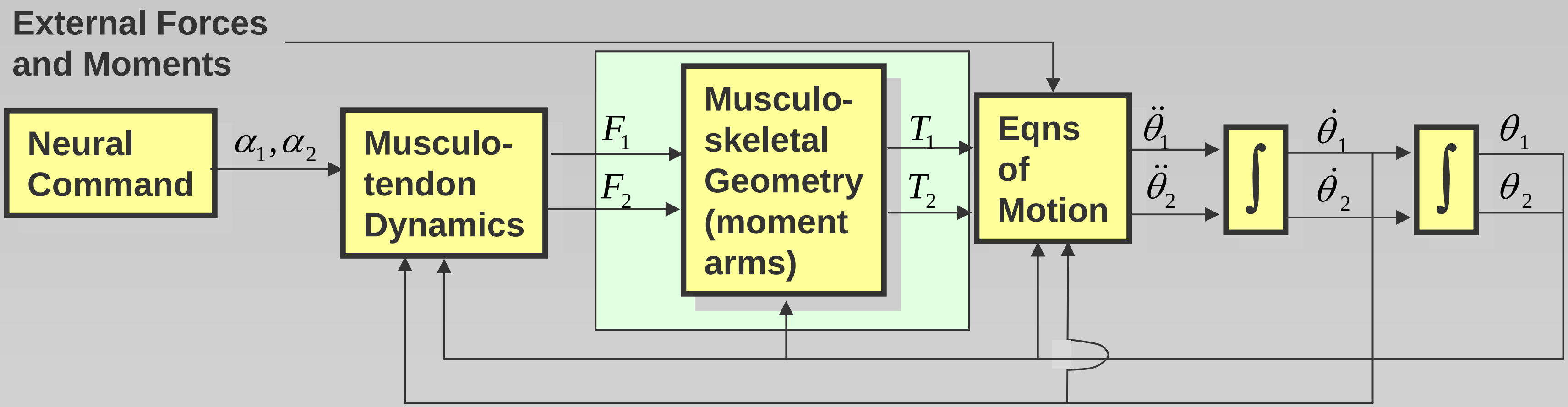

1. Systems-level Modeling
2. Multi-joint Dynamics
3. Musculoskeletal Geometry

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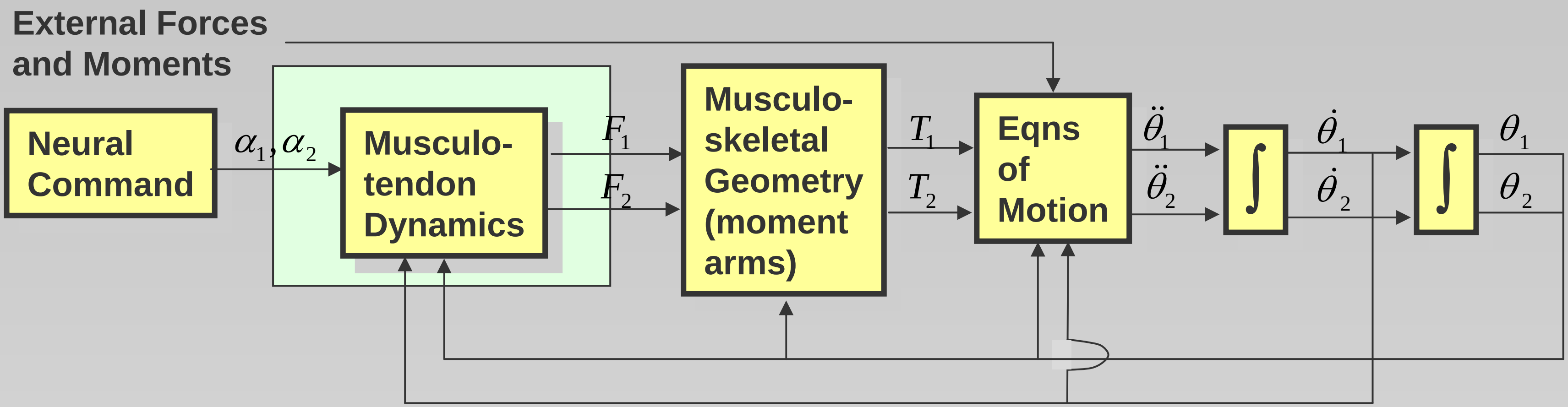

1. Systems-level Modeling
2. Multi-joint Dynamics
3. Musculoskeletal Geometry
4. Muscle-tendon Dynamics

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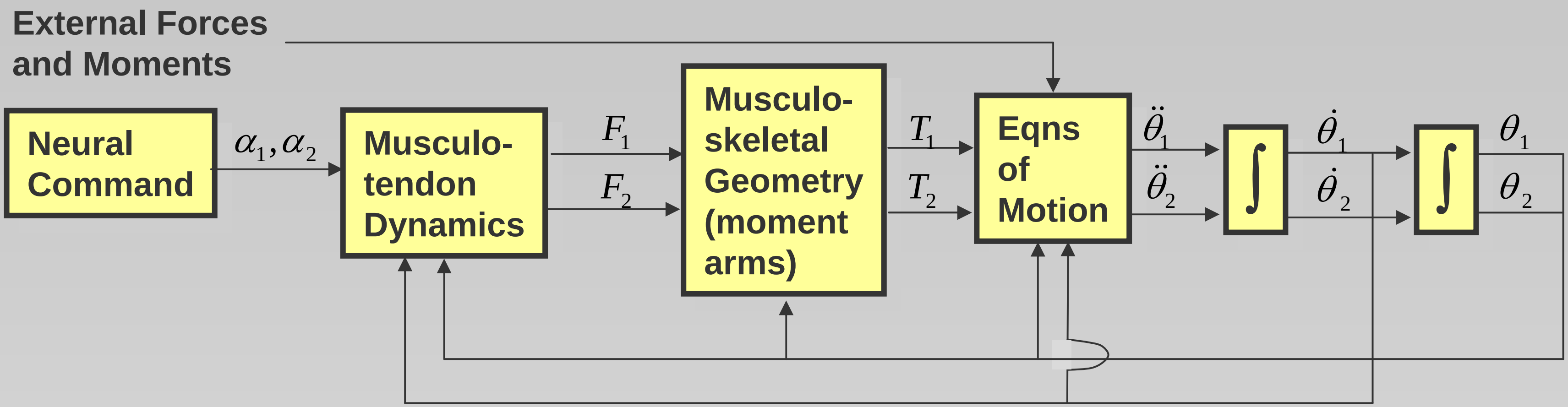


1. Systems-level Modeling
2. Multi-joint Dynamics
3. Musculoskeletal Geometry
4. Muscle-tendon Dynamics
5. Systems-level Modeling

Journal Review Instructions

- The purpose of reviewing these papers is to supplement and broaden the lab experience.
- Student reviews of papers will make the course more interesting, fun, and instructive.
- The reviews will involve both a class presentation and a written handout (see review instructions).
- The class presentation should be approximately 20 minutes (including discussion).

Journal Article Review

1. The basic principles of movement coordination remain unclear, despite years of detailed recording and analysis of kinsiological data. Why?

Journal Article Review

1. The basic principles of movement coordination remain unclear, despite years of detailed recording and analysis of kinsiological data. Why?
2. Forward dynamic simulation, used in conjunction with experimental measurements and optimization theory, is the most promising method for elucidating movement coordination principles.

Journal Article Review

- Outline:
  - Why is understanding muscle coordination of movement complex?
  - Muscle function based on anatomical classification
  - System mass matrix
  - Forward versus inverse dynamics
- Do dynamics-based models really help?
  - Why forward dynamics?
  - Jumping: a convincing example
- What do you think?

Anatomical Classification

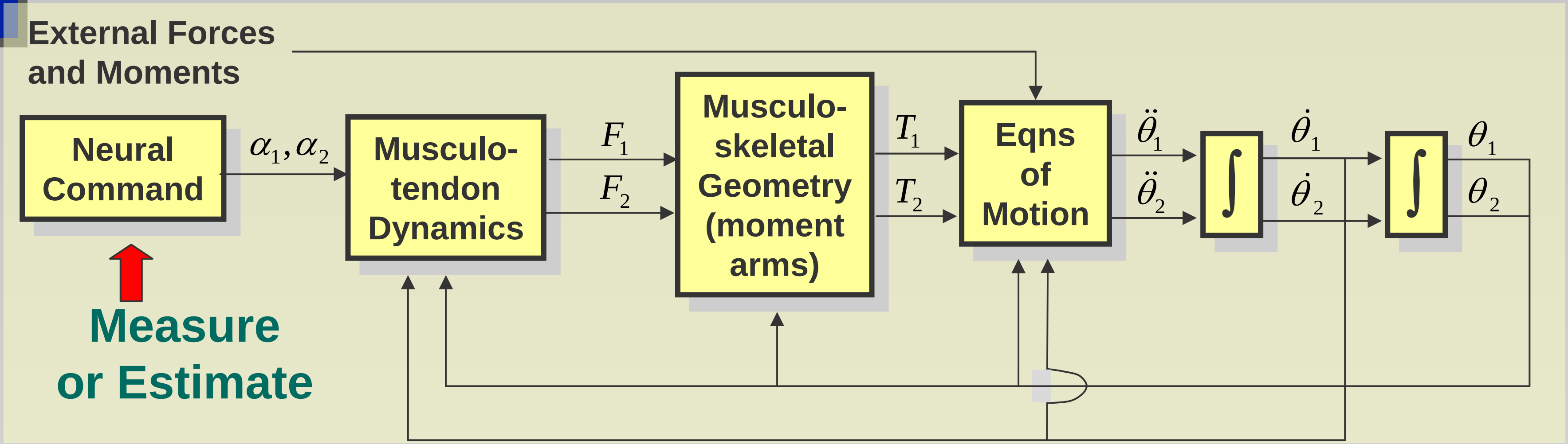
- Muscles are often classified based on the joint torques they produce
  - At which joints can a muscle produce a torque?
  - Will the direction that a muscle acts to accelerate a joint always be in the same direction as the torque it develops? Consider uniarticular vs biarticular muscles
- A muscle may accelerate a joint it does not span more than the joint it spans
  - Dynamic coupling
  - System mass matrix

System Dynamical Equations

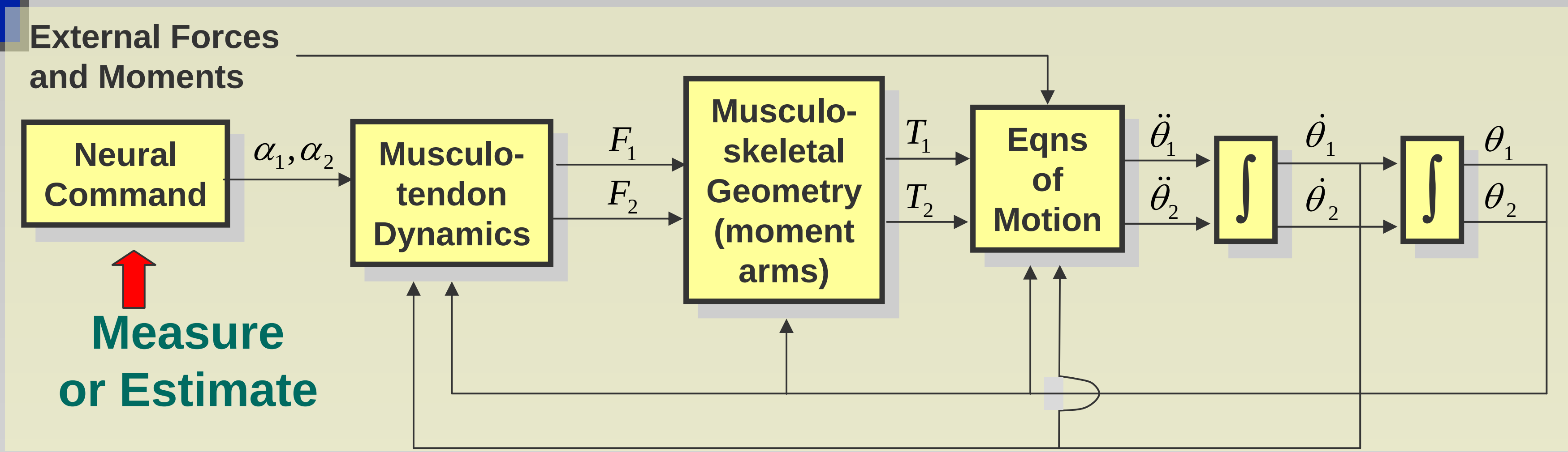
$$\ddot{\bar{\mathbf{q}}} = \mathbf{M}(\bar{\mathbf{q}})^{-1} \cdot \{\mathbf{C}(\bar{\mathbf{q}}, \dot{\bar{\mathbf{q}}}^2) + \mathbf{G}(\bar{\mathbf{q}}) + \mathbf{R}(\bar{\mathbf{q}}) \cdot \bar{\mathbf{f}}_{\mathbf{M}} + \mathbf{E}(\bar{\mathbf{q}})\}$$

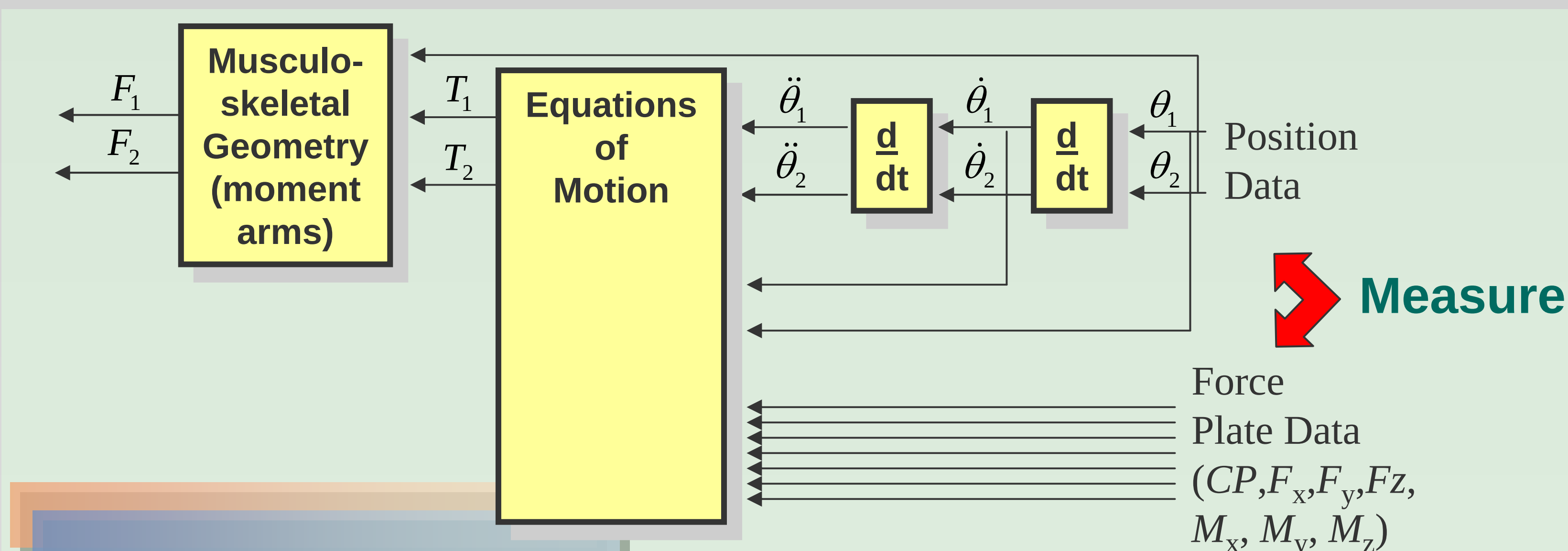
- Characterizes the inertial properties of the body
- Mass matrix provides a geometric transformation between forces and accelerations
- Critical for understanding how forces contribute to joint accelerations
- Task dependent, that is, how muscles accelerate joints varies from task to task.

Forward vs Inverse Dynamics



Forward vs Inverse Dynamics





Forward Dynamics Difficulties

- Computationally intensive
- Difficult to produce a well coordinated movement
  - Optimal tracking
    - e.g., minimize experimental RMS errors
  - Hypothesize goal of the motor task
    - e.g., maximize jump height, minimize energy expenditure
- Compatibility between forward and inverse dynamics
  - Can you use joint torques derived from inverse dynamics to drive a forward dynamics simulation?
    - Kinematic data are inaccurate (i.e., pos, vel, acc estimates)

Analysis of Jumping

- Should leg muscles be maximally activated?
- Should you train for strength or speed?
- How much does elastic energy contribute?
- Why do we counter move?
  - Force build-up, stretch-shortening effects
- What is the role of uniarticular vs biarticular muscles?

Why Not Use Simulation More?

- Considerable effort to develop and test models
- Difficulty in finding muscle controls
- Systems can be unstable
- Complex subject-specific models are just now being developed
- EML 5595!

Summary

- Understanding muscle coordination in multi-joint movement is complex because muscle forces affect many body segments.
- Forward dynamics models provide an effective means to study muscle coordination.
- Forward dynamics models usually need some kind of control. Optimization and tracking techniques provide reasonable methods.
- Further work that combines models with experiments is needed to help elucidate coordination principles.
- Subject-specific models are required to make these approaches clinically relevant.

For Next Time

- Download and work through SIMM Tutorial 3
- Download and read Lu and O'Connor (1999)
- Review the new reference materials and suggestions posted on the course web site