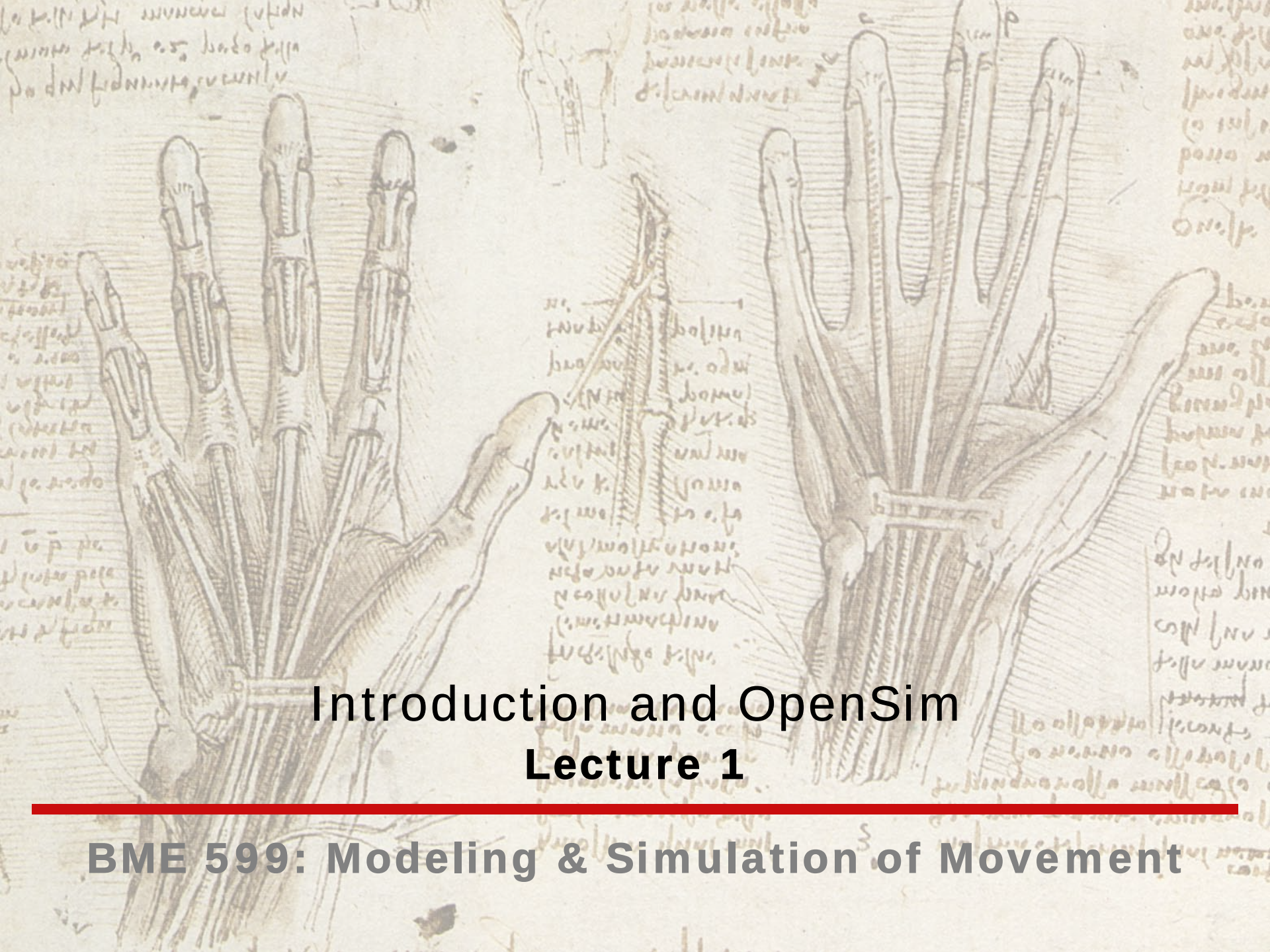

Introduction and OpenSim

Lecture 1

BME 599: Modeling & Simulation of Movement

Question of the Day

What is simulation & why is it important?

Outline for Today

- Question of the day
- Who am I? Who are you?
- What is in the syllabus and handouts?
- Objectives of the lectures and assignments
- Why simulate movement?
- Movement results from many elements
- What software will we use?
- What can you do with this stuff?
- Prerequisites for modeling and simulation
- Answer your questions!

Who am I?

- Originally from Florida

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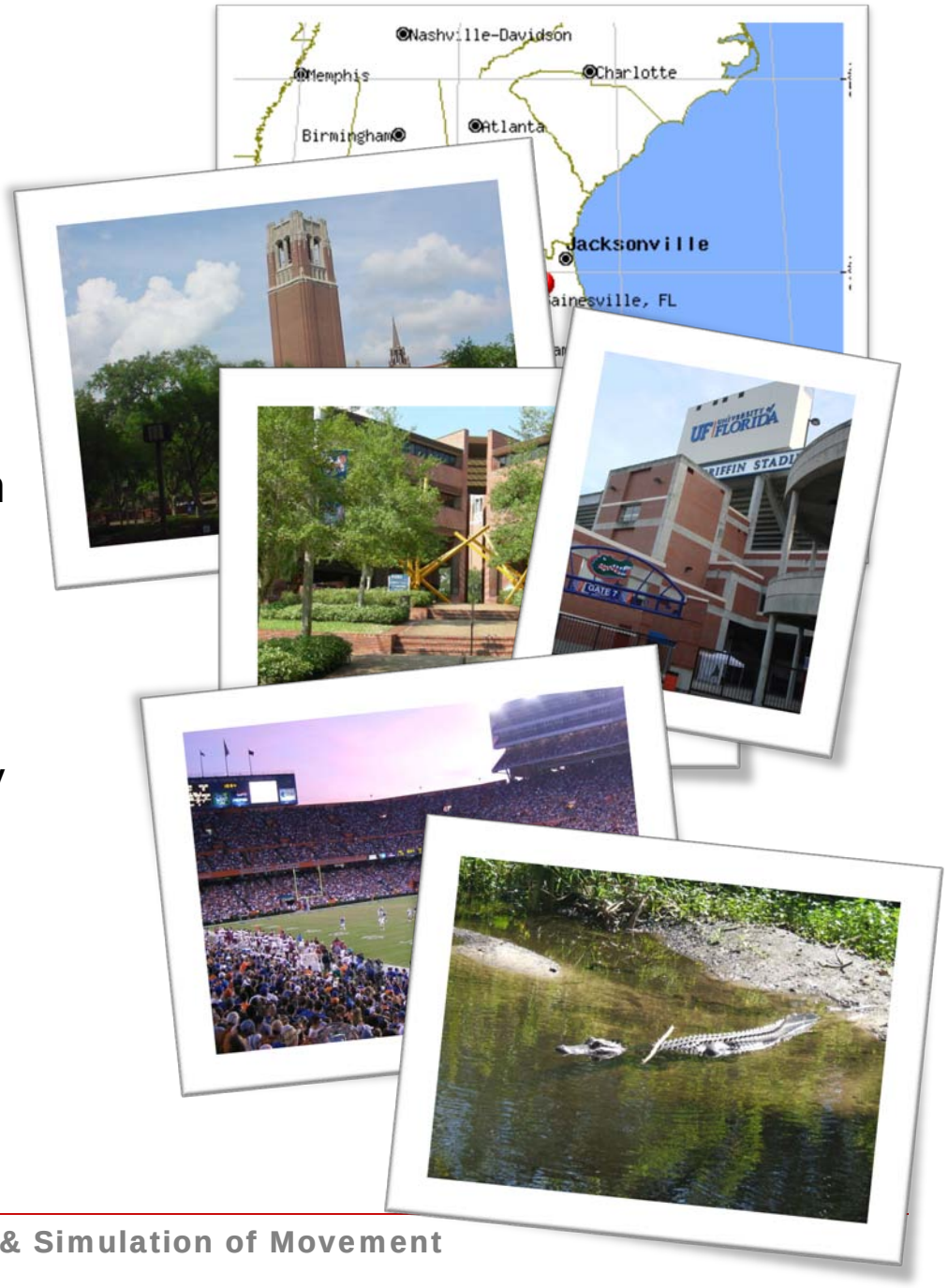

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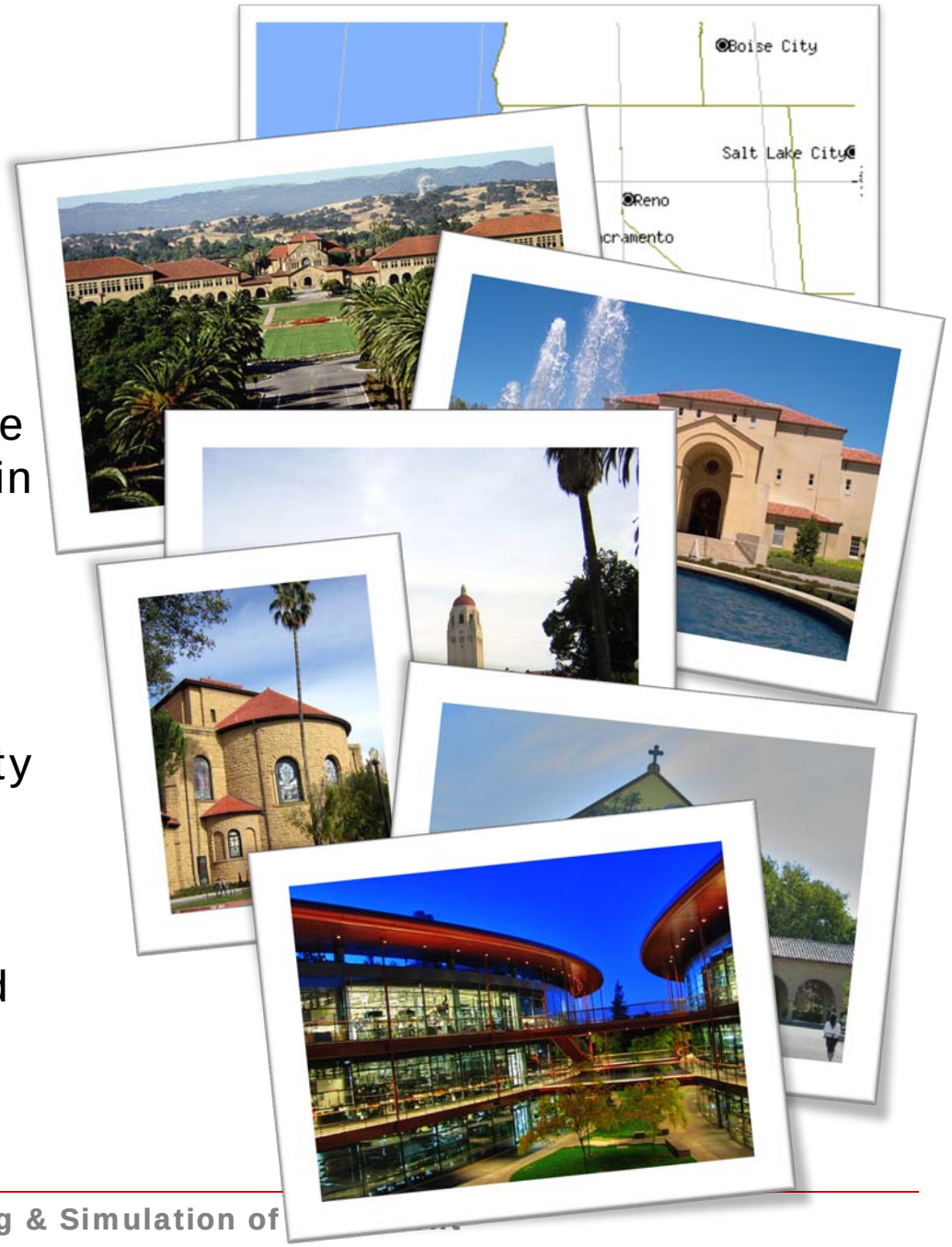

Who am I?

- Originally from Florida
- B.S. in Engineering Science from University of Florida in 1996
- Biomedical Engineer for Computer Motion, Inc.
- Ph.D. in Mechanical Engineering from University of Florida in 2006
- Postdoc & Engineering Research Associate in Bioengineering at Stanford
- Married with two children
- Enjoy learning, volleyball, biking, and being outdoors

Who are you?

1. Where were you born?
2. What is something unique about where you grew up?
3. What sports do you like?
4. Why are you taking simulation of movement?
5. What do you want to do after you graduate?

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What is in the syllabus and handouts?

THE UNIVERSITY of TENNESSEE KNOXVILLE
COLLEGE of ENGINEERING

COURSE SYLLABUS
BME 599 ~ Modeling & Simulation of Human Movement
Spring 2012

Course Section:	**002**
Meeting Time and Place:	**2:10PM – 3:25PM | TR | Perkins 61**
Course Credit Hours:	**3**

FACULTY CONTACT INFORMATION	Jeff Reinbolt Office hours: 3:40PM - 4:55PM TR Office: DO 207 Phone: 865.974.5308 Email: *reinbolt@utk.edu*
TEACHING ASSISTANT CONTACT INFORMATION	Not applicable

What is in the syllabus and handouts?

LECTURE SCHEDULE

BME 599 ~ Modeling & Simulation of Human Movement

Month		Tuesday		Thursday
January	10		12	Introduction and OpenSim (Delp)
	17	Lab 1: Jumping Simulation (Anderson-99)	19	Systems-level Modeling (Buchanan, Erdemir, Zajac-93)
	24	Muscle Moment Arm (Arnold-00, Blemker, Delp-99)	26	Inverse Kinematics (De Groote-08, Lu)
	31	Lab 2: Kinematic Modeling		
February			2	Inverse/Forward Dynamics (Gilchrist, Remy)
	7	Patient-specific Modeling (Reinbolt-05, Reinbolt-07)	9	Adv. Dynamic Analyses (Fregly-96, Higginson)
	14	Lab 3: Torque Simulation	16	Dynamic Optimization (Fregly-07, Peasgood)
	21	Contact Modeling	23	Muscle Modeling

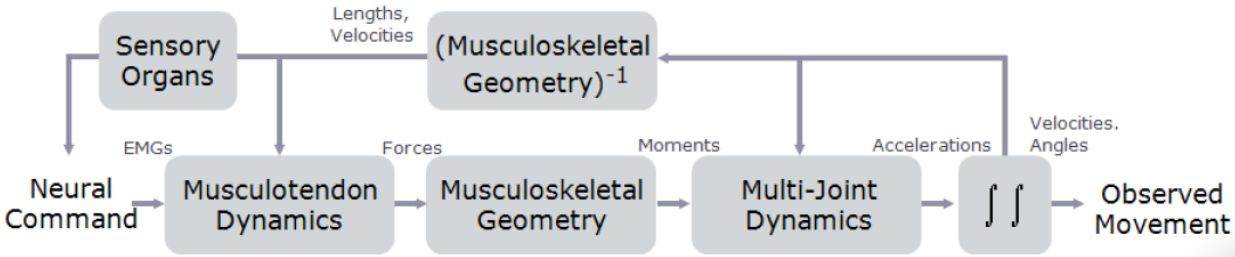
What is in the syllabus and handouts?

SIMULATION LABS

BME 599 ~ Modeling & Simulation of Human Movement

Overview

Human movement requires the coordination of many muscles. The transformation between neural control and purposeful movement is highly complex and involves many individual elements.



First, a neural command is given to excite certain muscles; the electrical potential of which can be recorded with electromyography (EMG). Second, muscle-tendon dynamics based on length and velocity properties of the muscle and tendon produce muscle forces. Third, musculoskeletal geometry defines the location of joints, the direction of muscle forces, and muscle moment arms to produce joint moments. Fourth, given

What is in the syllabus and handouts?

COURSE PROJECT

BME 599 ~ Modeling & Simulation of Human Movement

Objective of Assignment

The purpose of the project is to combine as many concepts from the course as possible to perform a study that will allow you to see "how all the pieces fit together." This project is designed to be completely open-ended and you will have free reign to pick a topic in the field of biomechanics that you are interested in. You should meet with me to determine a suitable topic. My hope is that by the end of the project, you will have a solid understanding of how kinematics, dynamics, geometric modeling, forward and inverse dynamics, and optimization all play an important role in the analysis of the human musculoskeletal system. This project will give you a chance to deepen your knowledge in an area of biomechanics that interests you. I expect that you will remember what you learn from this project long after the class is over.

The course project is much more similar to an actual research project than to a homework assignment. Thus, you will encounter problems along the way that the instructor will not necessarily know how to resolve. You will therefore need to use the same skills necessary to perform successfully in a research lab – creativity, ingenuity, tenacity, and resourcefulness. OpenSim user manuals, OpenSim tutorials, the OpenSim user group, and other students in the course will all be critical resources for

What is in the syllabus and handouts?

JOURNAL ARTICLE REVIEW ASSIGNMENTS

BME 599 ~ Modeling & Simulation of Human Movement

Month		Tuesday		Thursday
January	10		12	Dr. Reinbolt (Delp)
	17	Dr. Reinbolt (Anderson-99)	19	Dr. Reinbolt (Buchanan, Erdemir, Zajac-93)
	24	Dr. Reinbolt (Arnold-00, Blemker, Delp-99)	26	1._____ (De Groote-08) 2._____ (Lu)
	31			
February			2	3._____ (Gilchrist) 4._____ (Remy)
	7	5._____ (Reinbolt-05) 6._____ (Reinbolt-07)	9	7._____ (Fregly-96) 8._____ (Higginson)
	14		16	9._____ (Fregly-07) 10._____ (Peasgood)
	21	11._____ (Gilchrist)	23	13._____ (Buchanan) 14._____ (Pandy)

What is in the syllabus and handouts?

COURSE READER

BME 599 ~ Modeling & Simulation of Human Movement

1. Delp SL, Anderson FC, Arnold AS, Loan P, Habib A, John CT, Guendelman E, Thelen DG. OpenSim: Open-source software to create and analyze dynamic simulations of movement. *IEEE Transactions on Biomedical Engineering* 54(11):1940-50, 2007.

2. Anderson FC, Pandy MG. A dynamic optimization solution for vertical jumping in three dimensions. *Computer Methods in Biomechanics and Biomedical Engineering* 2(3):201-31, 1999.

3. Zajac FE. Muscle coordination of movement: a perspective. *Journal of Biomechanics* 26(Suppl 1): 109-24, 1993.

4. Buchanan TS, Lloyd DG, Manal K, Besier TF. Neuromusculoskeletal modeling: estimation of muscle forces and joint moments and movements from measurements of neural command. *Journal of Applied Biomechanics* 20(4):367-95, 2004.

Outline for Today

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- Who am I? Who are you?
- What is in the syllabus and handouts?
- Objectives of the lectures and assignments
- Why simulate movement?
- Movement results from many elements
- What software will we use?
- What can you do with this stuff?
- Prerequisites for modeling and simulation
- Answer your questions!

Objectives of the Lectures and Assignments

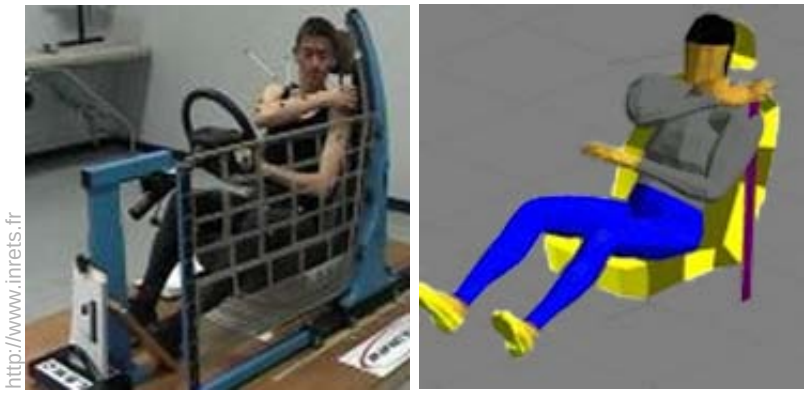
- This course will enable you to create dynamic simulations of movement.
- The course is organized around the system involved in the production of voluntary movement.
- You will develop mathematical models for each component and implement the models in computer software.
- You will analyze computer simulations to gain insight into movement biomechanics.

Other Stuff About the Lectures and Assignments

- This is the first time this course has been offered at UTK. We will need to make some adjustments. Please give feedback.
- You will need to dig beyond lecture and lab notes to complete the assignments.
- Developing dynamic simulations of movement does not involve the typical process of learning.
- This class will require a significant effort.
- Be interactive! Contribute! Have fun!

Why Simulate Movement?

Analyze and optimize athletic performance

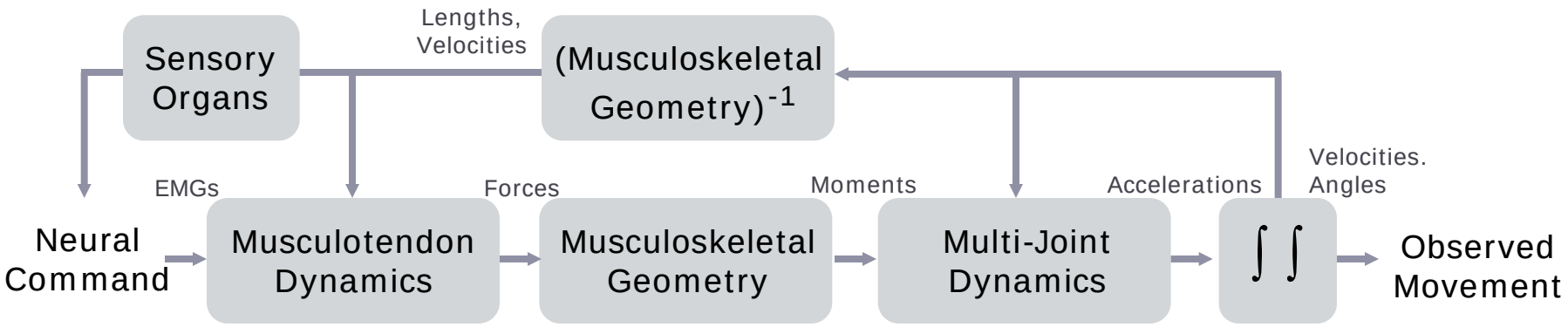


Design ergonomically safe environments

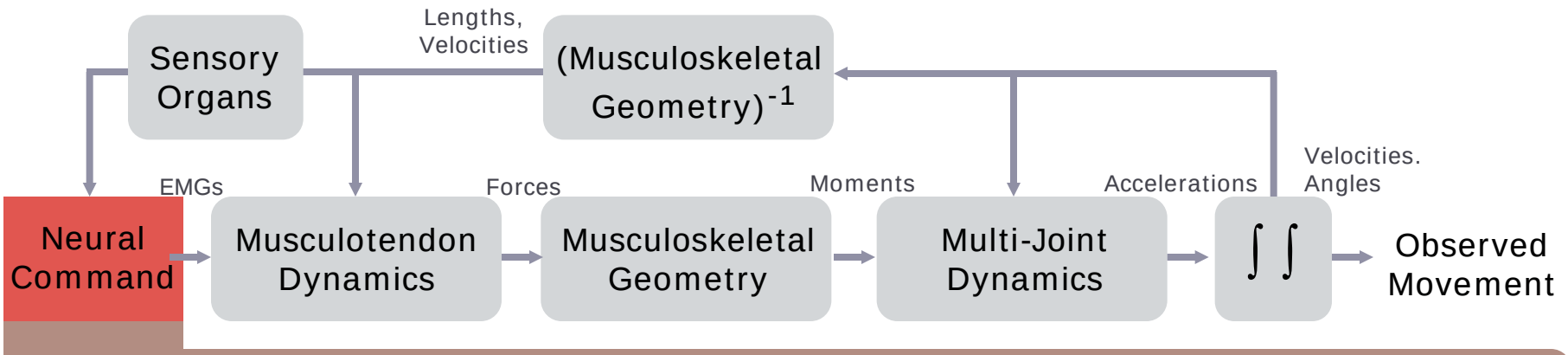
Create human and animal characters

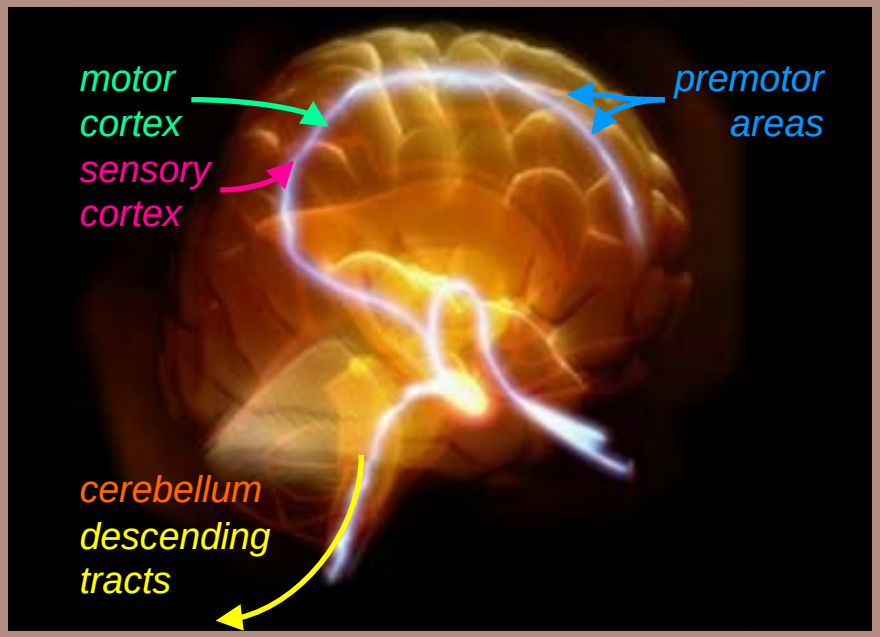
Understand and treat movement disorders

Movement Results from Many Elements

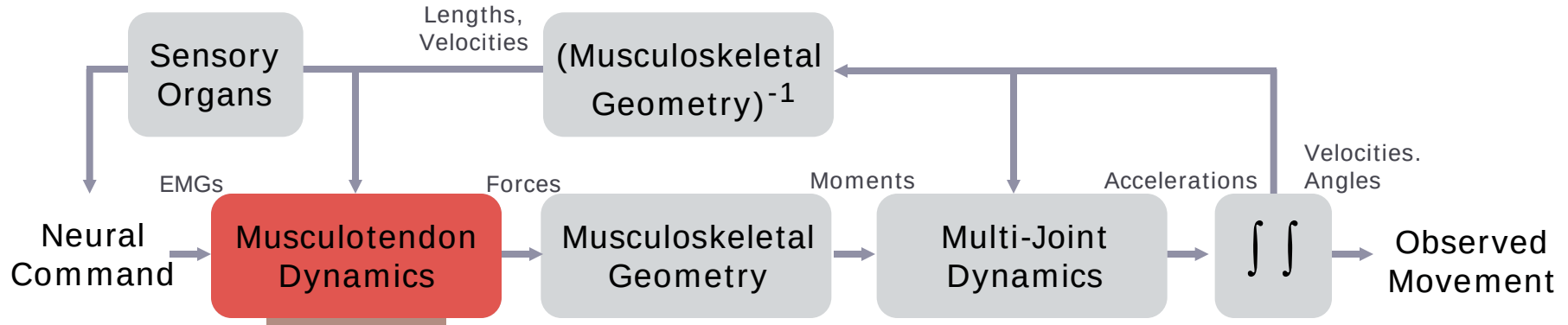


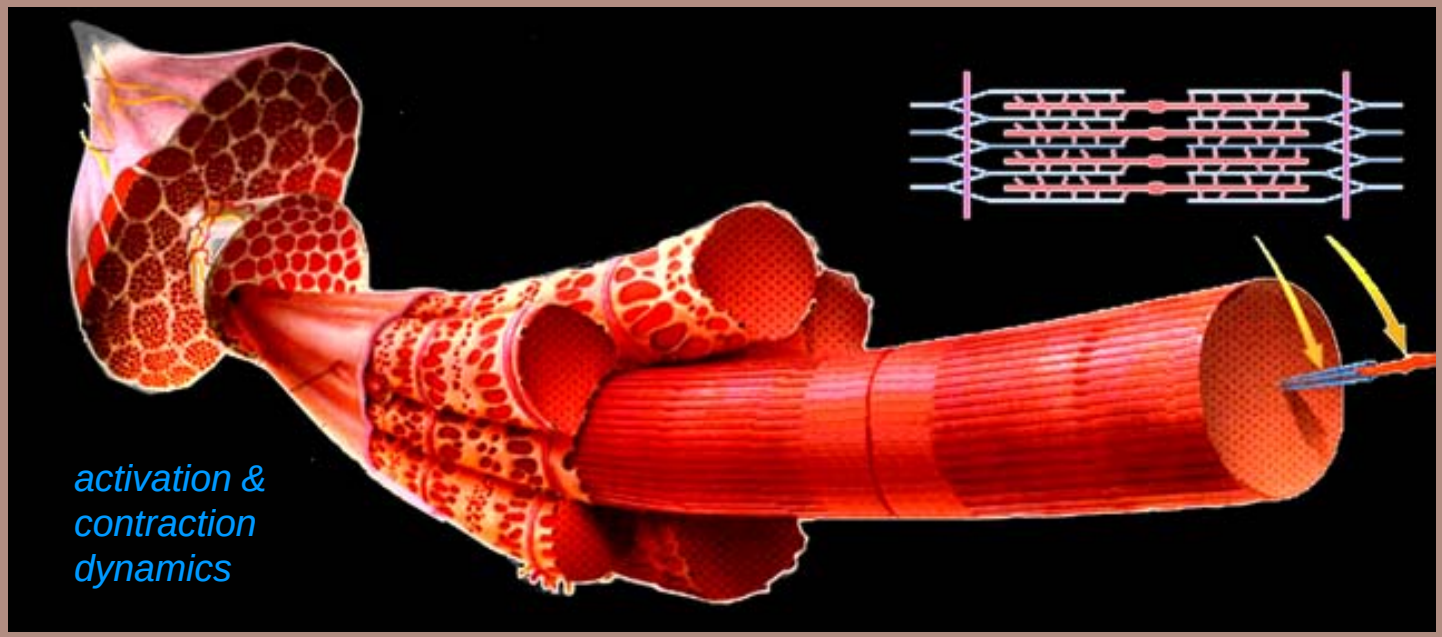
Movement Starts with a Neural Command





From EMGs to Forces





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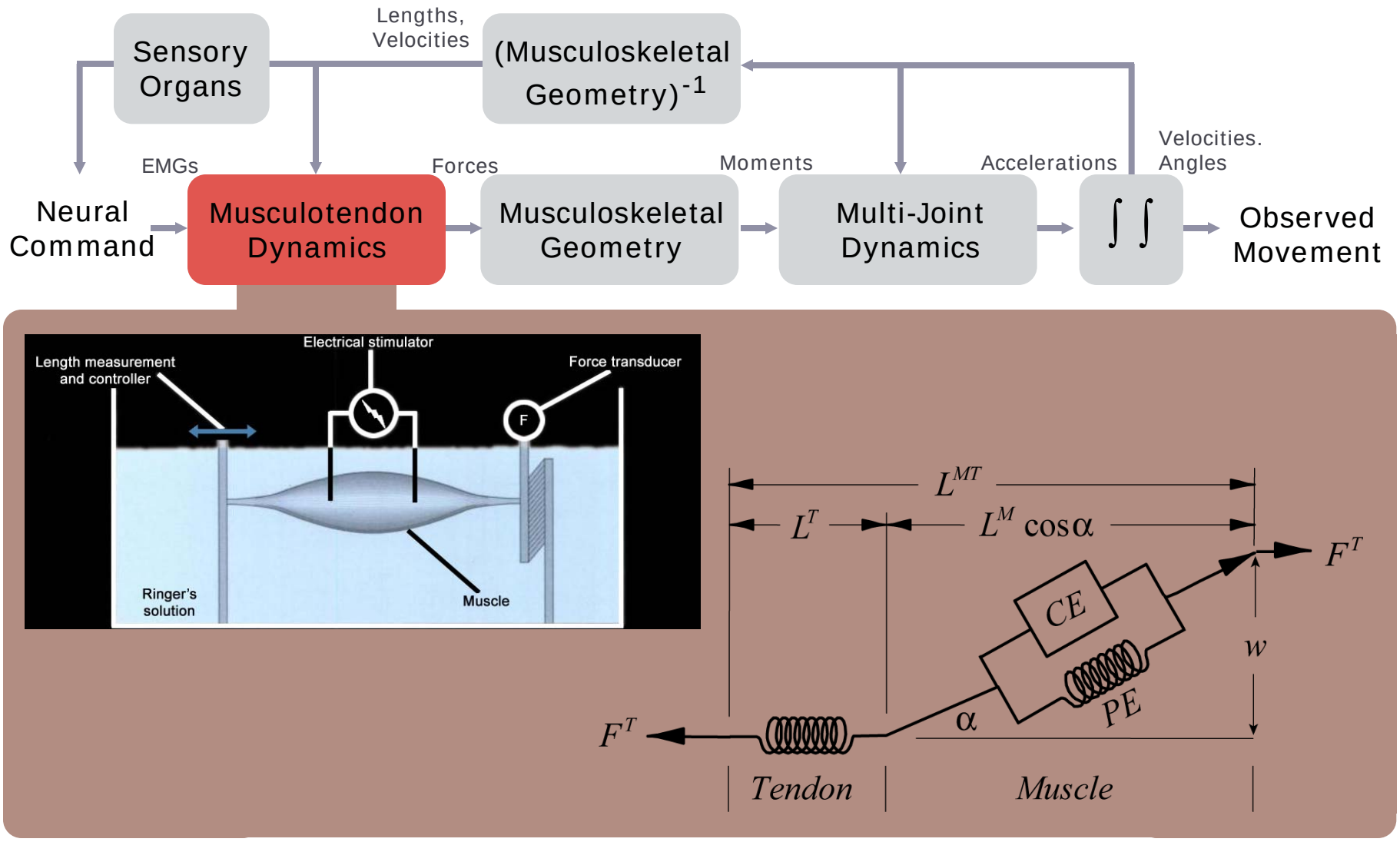
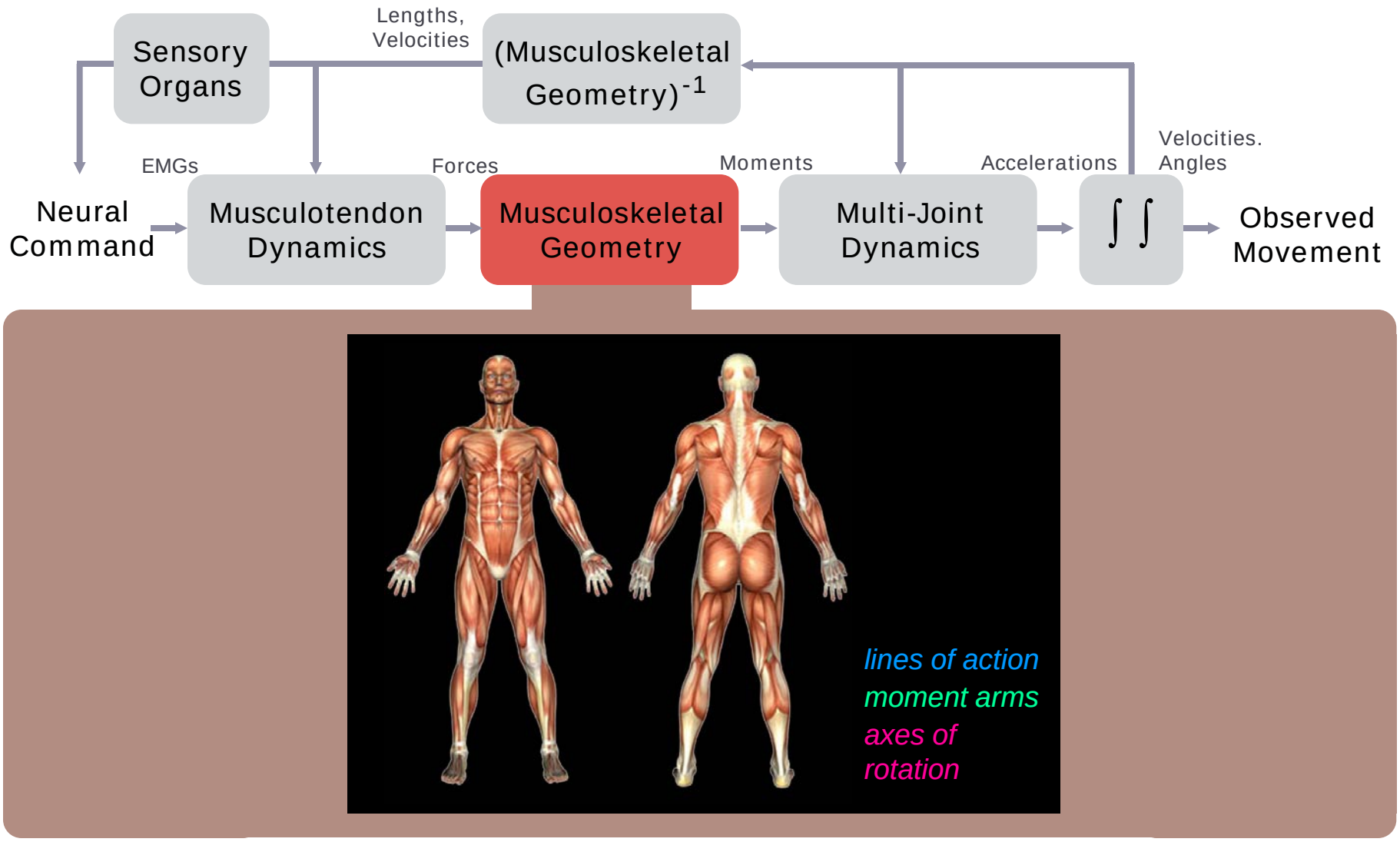
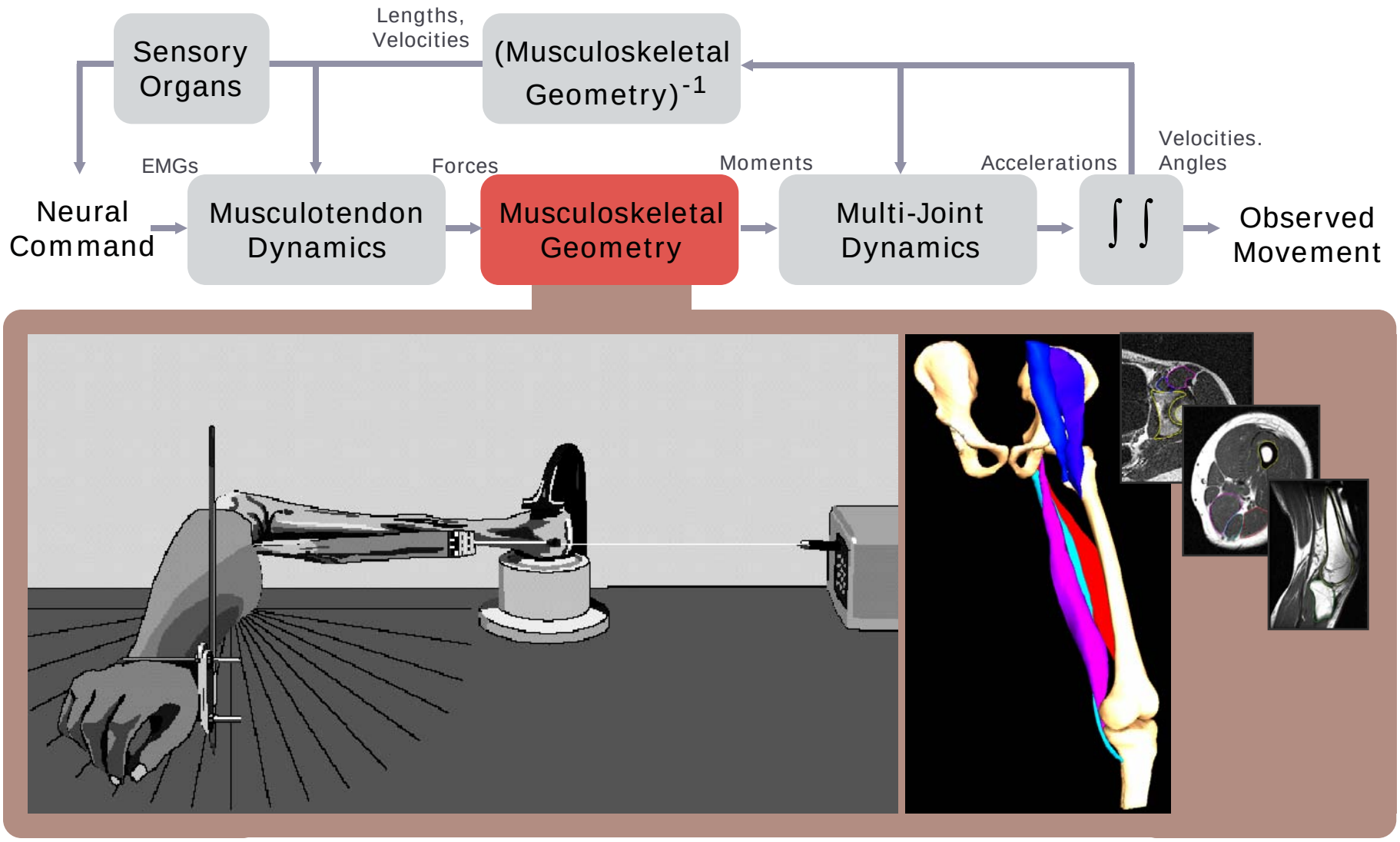


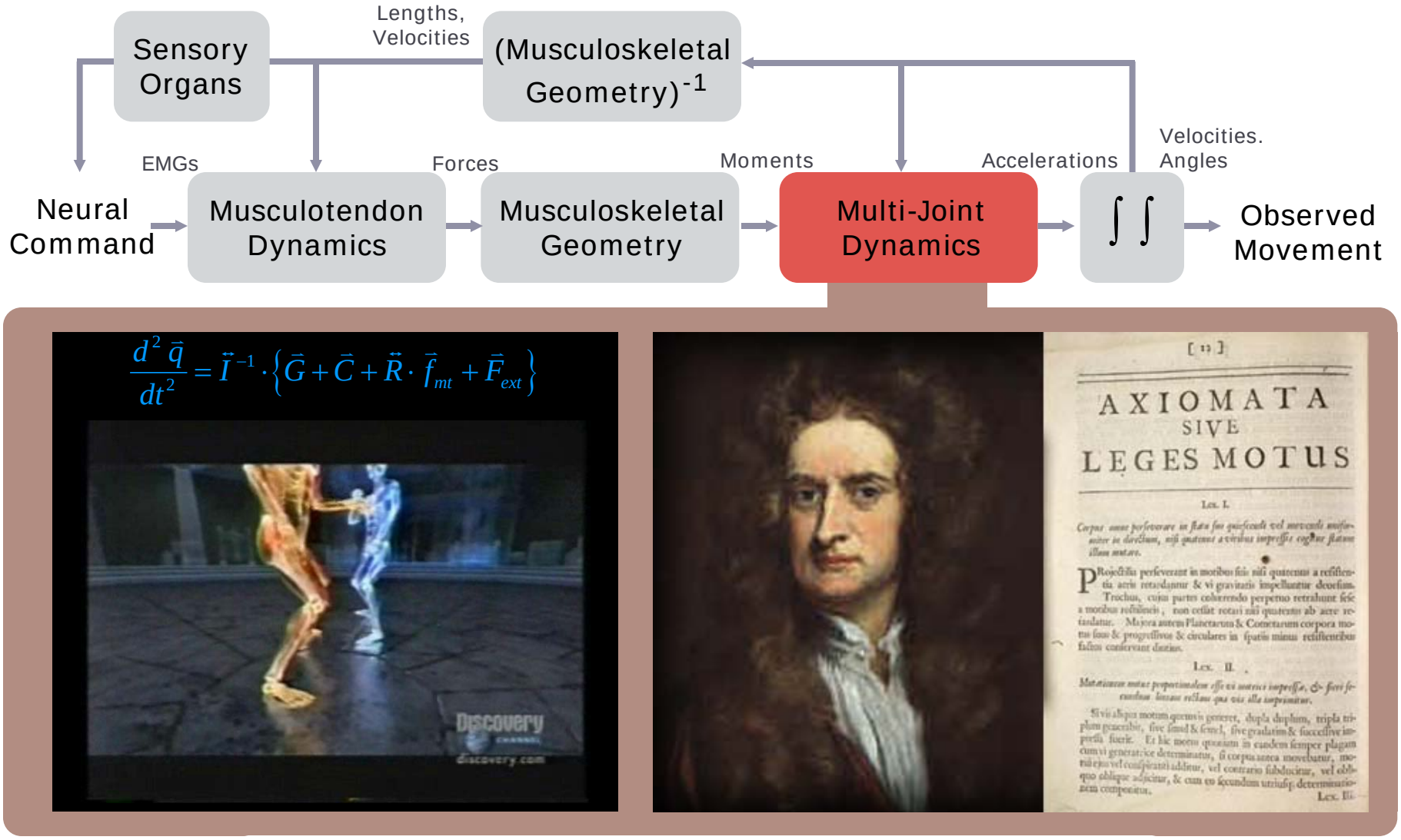
From Forces to Moments



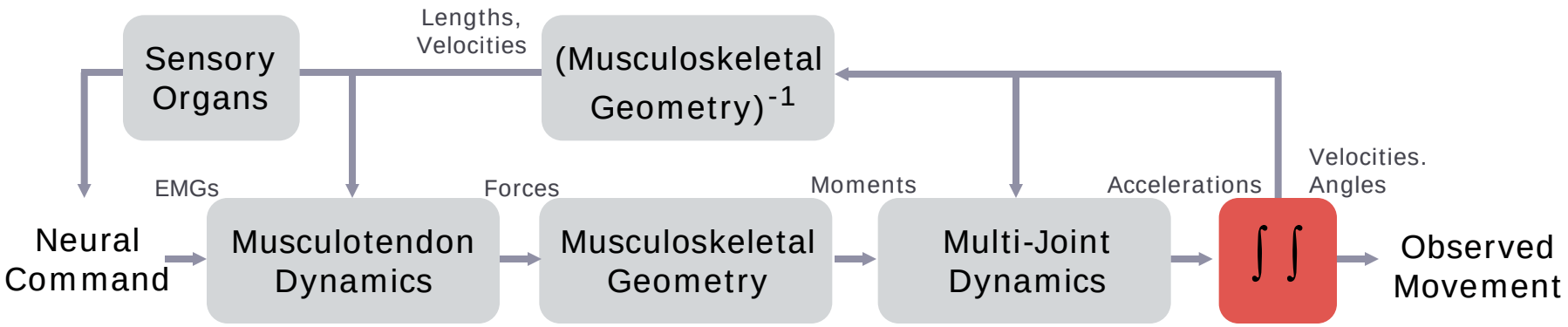
From Forces to Moments



From Moments to Accelerations

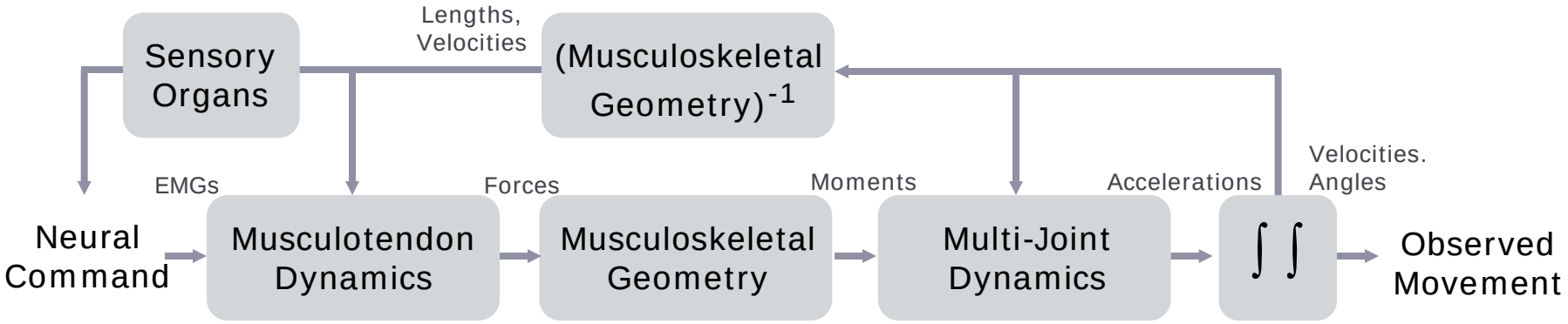


From Accelerations to Positions (movement)



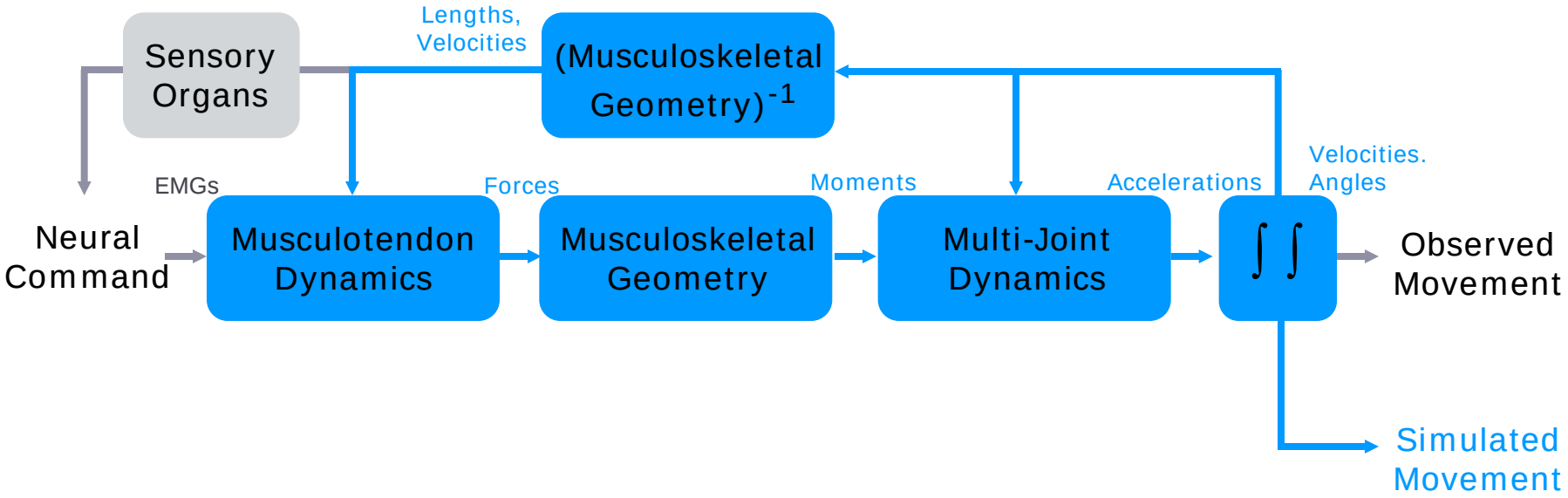
Integrating equations of motion is generally a straightforward procedure.

Experiments Alone Have Limitations to Understanding Movement Dynamics

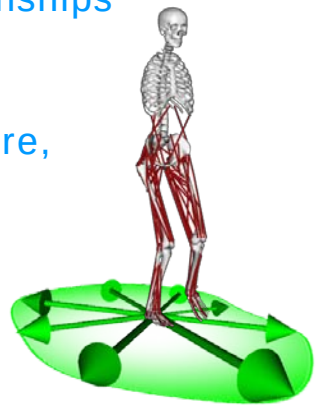


- Difficult to establish cause-effect relationships (e.g., muscle function)
- Important variables (e.g., muscle and joint forces) are not generally measurable

Simulations Complement Experimental Approaches



- Difficult to establish cause-effect relationships (e.g., muscle function)
- Enable cause-effect relationships to be identified and allow "what if?" studies
- Relationships among posture, muscle forces, and ground reaction forces (e.g., crouch gait)



- Important variables (e.g., muscle and joint forces) are not generally measurable
- Provide estimates of important variables generating movement
- Design of new techniques for reducing injury risk in sports (e.g., sidestepping)

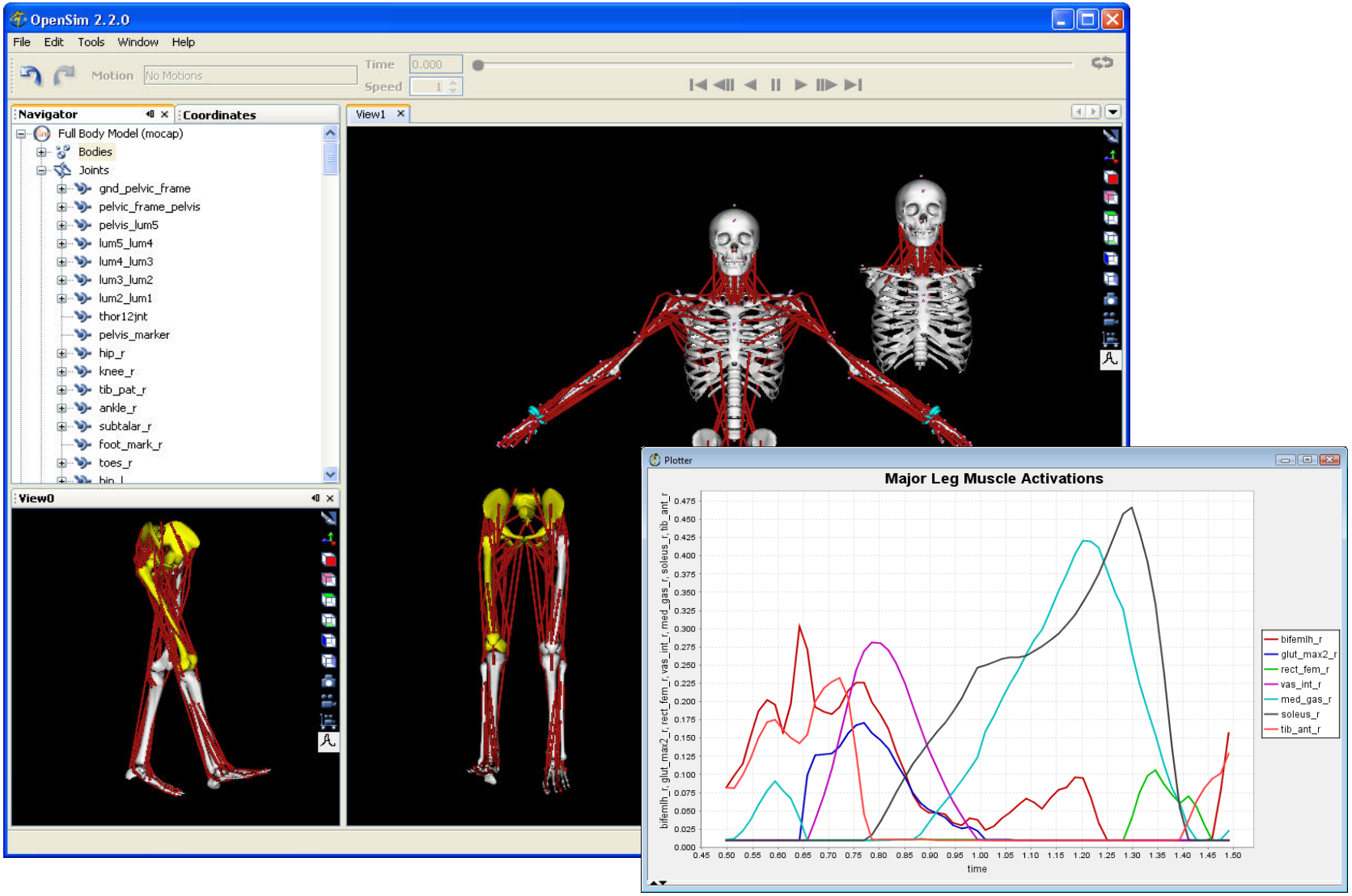
Software to Create and Analyze Dynamic Simulations of Human Movement

OpenSim

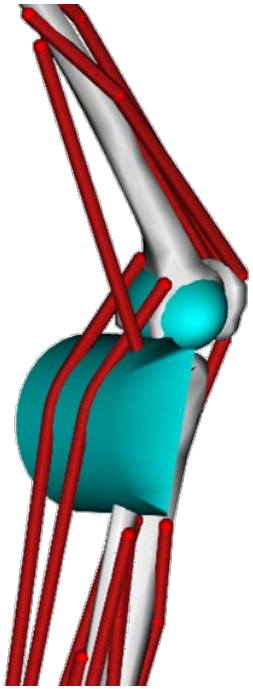
Patient-Specific Musculoskeletal Models and Dynamic Simulations of Movement

https://simtk.org/home/opensim

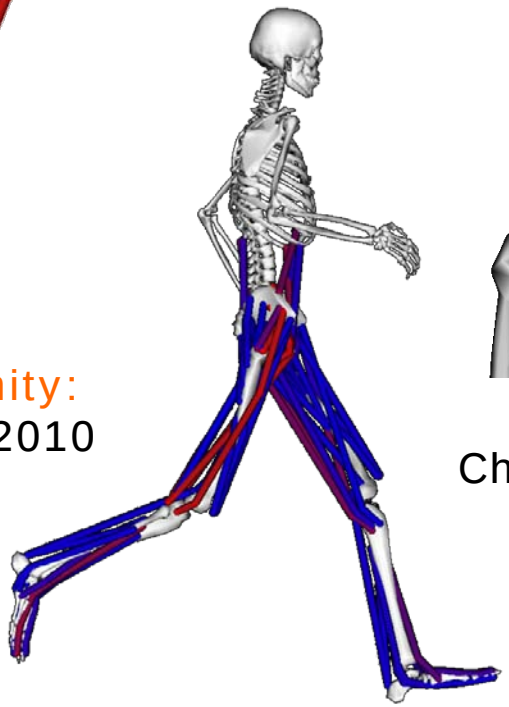
OpenSim is an application



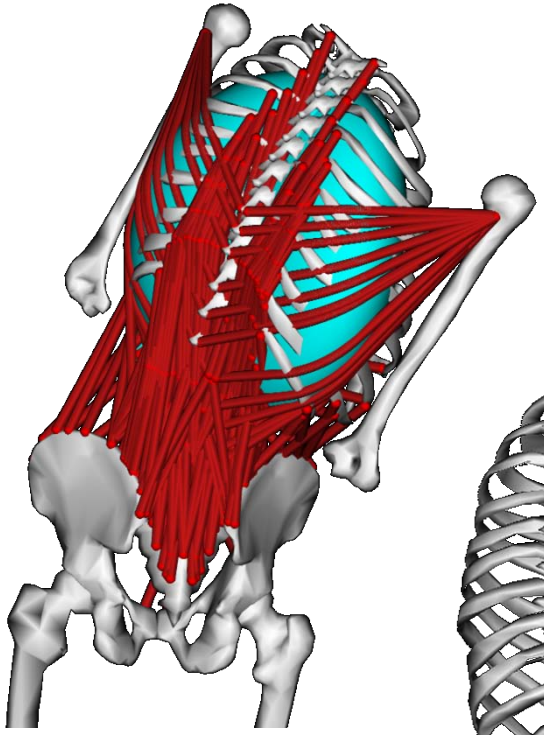
OpenSim is a repository of models, data, & tools



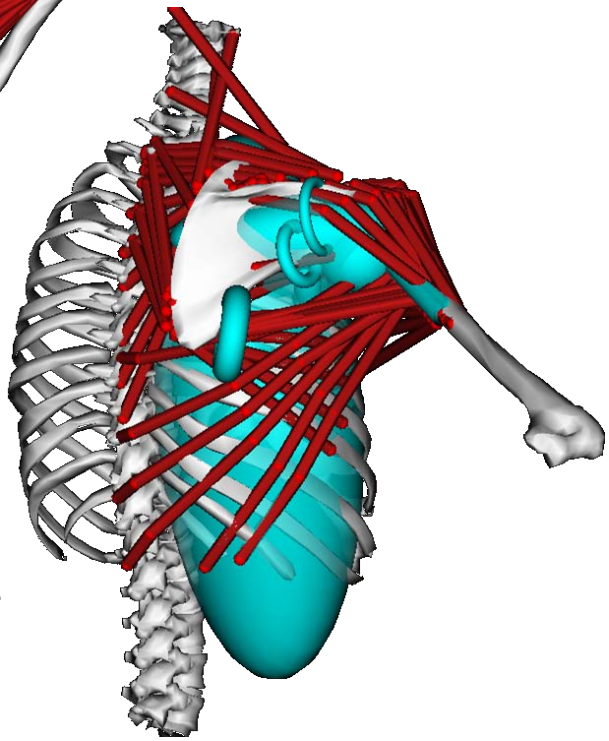
Lower-extremity:
Arnold et al, 2010



Running: Hamner et al, 2010



Lumbar-spine:
Christophy et al, 2011



Shoulder:
Matias et al, in prep.

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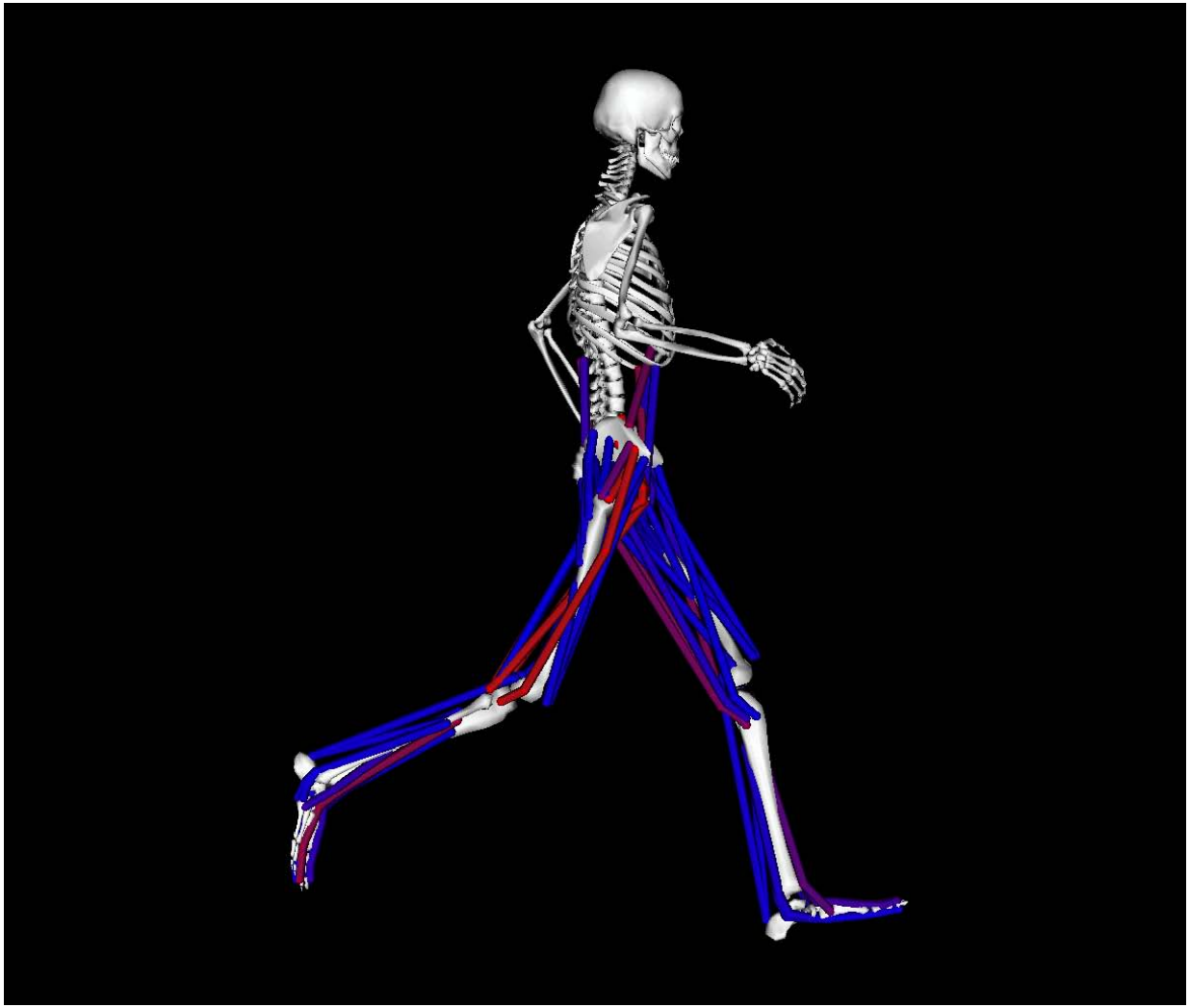
- Answer your questions!

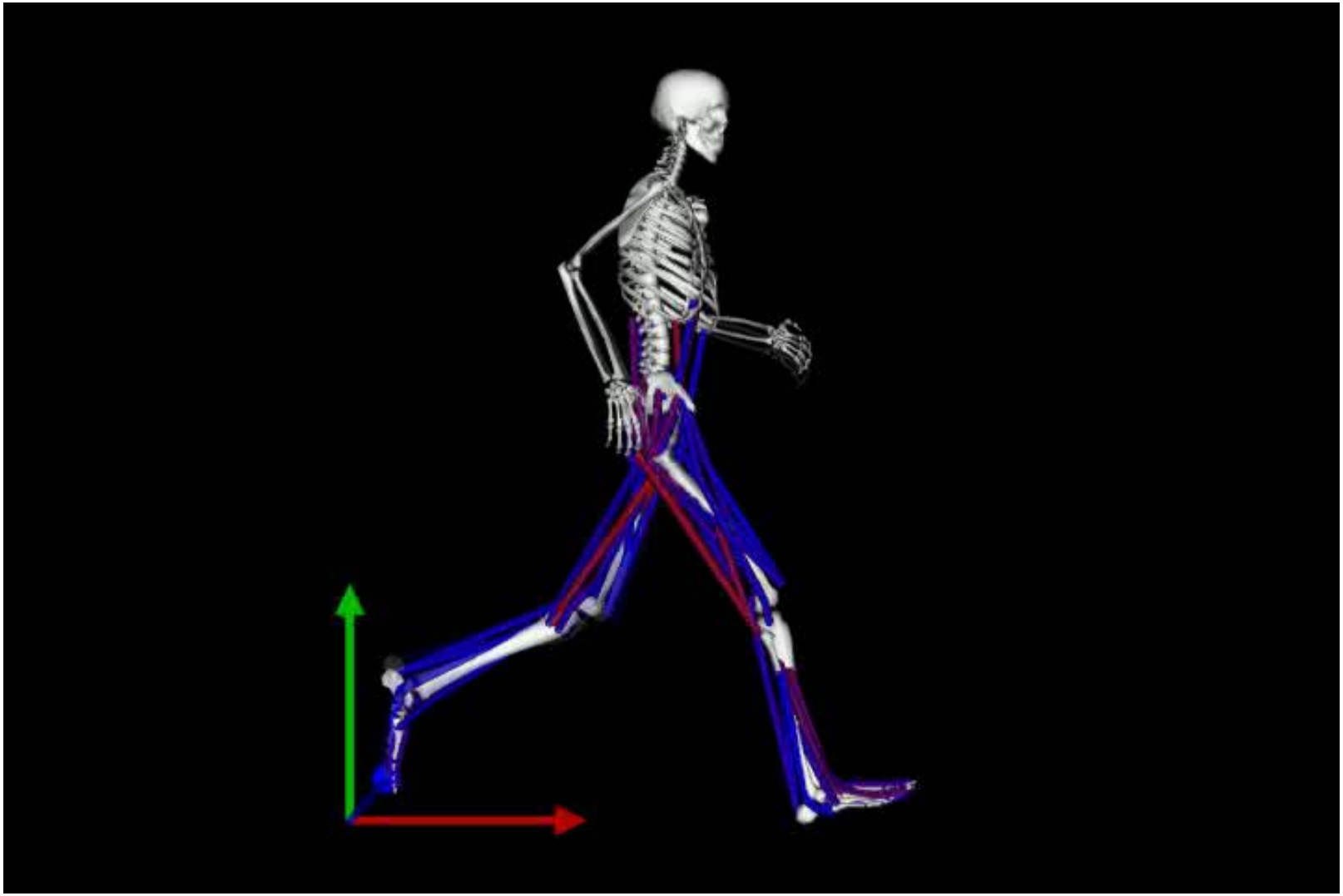
What can you do with this stuff?

- Access the literature and scientific meetings
- Solve important problems in biomechanics
  - Movement disorders (CP, Parkinsons, stroke)
  - Musculoskeletal disease (arthritis, osteoporosis)
  - Design of surgical procedures (tendon transfers, total joint replacement)
  - Sports performance and equipment
  - Ergonomics
  - Realistic computer animations
- Think differently about the world
- Do some good

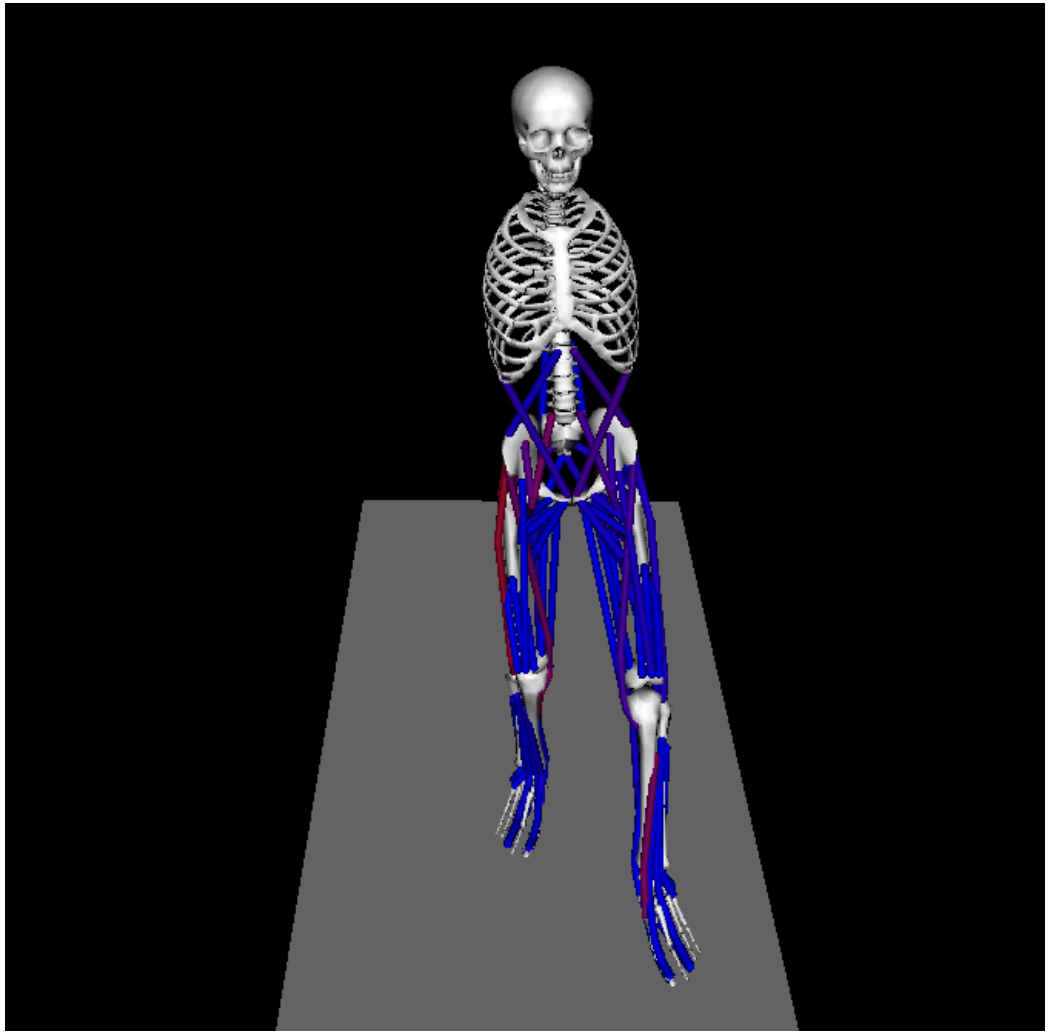
Visualize human running in detail



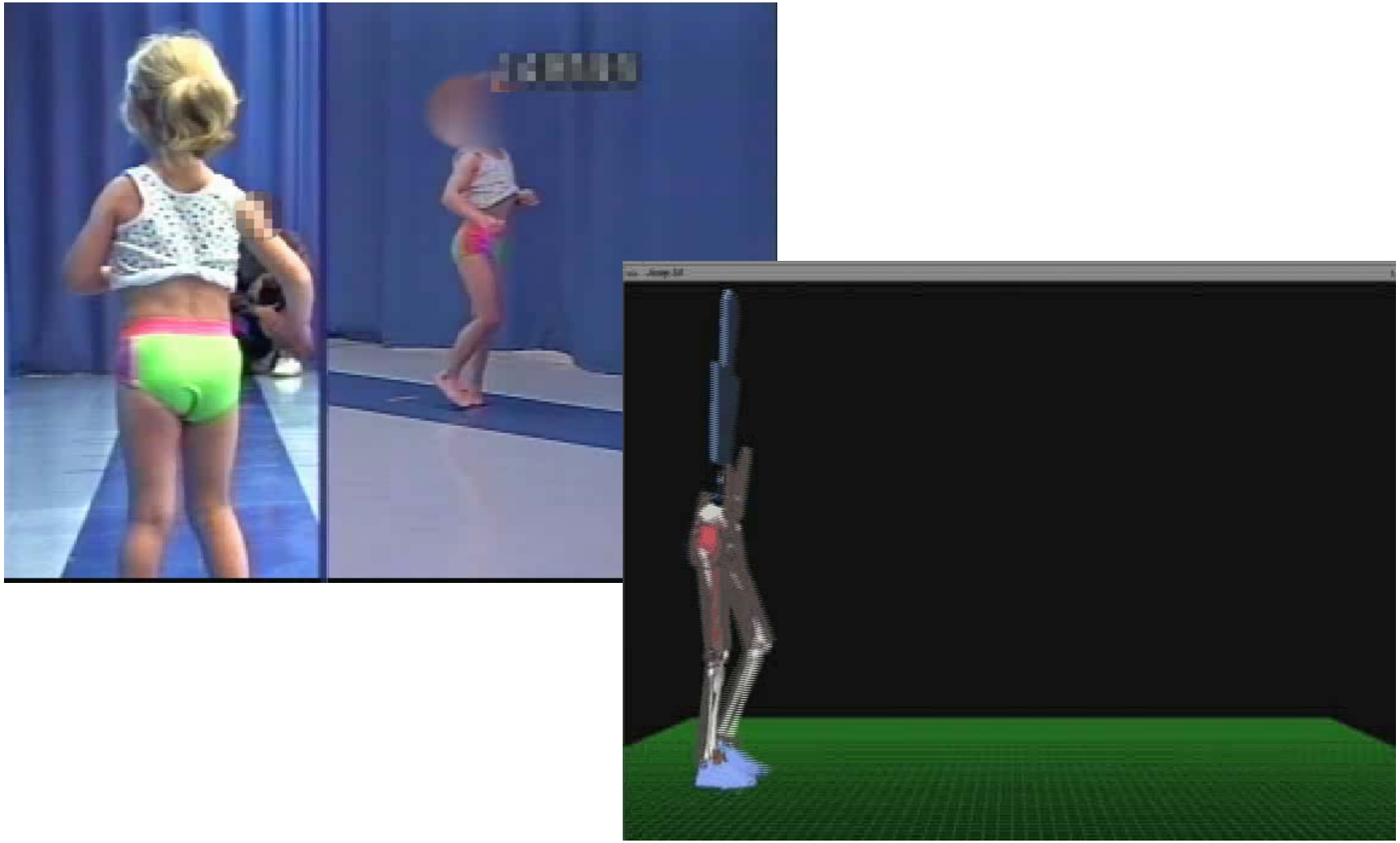
Probe the function of a muscle



Examine causes of crouch gait

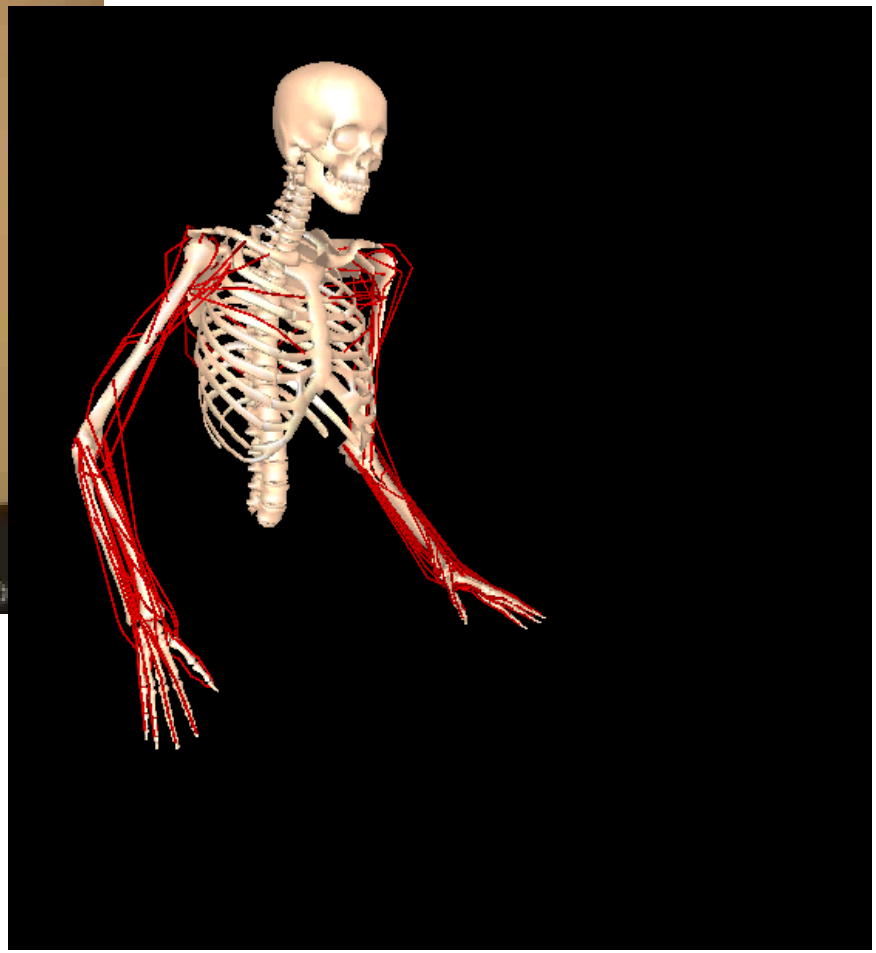


Biomechanics of Walking



Movies: Gillette Children's Hospital, Chand John

Biomechanics of the Upper Extremity



Movies: Terry Sanger and Kate Holzbaur

Prerequisites for Modeling and Simulation

- **Dynamics**: Specification of system, generating equations of motion, integration
- **Biomechanics**: Muscle activation dynamics, force-length-velocity properties, musculoskeletal geometry
- **Programming**: Mainly XML and MATLAB code
- **Initiative**: Searching manuals, struggling with assignments, being creative and diligent

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For Next Time…

- Read the first 2 articles of the Course Reader
  - Delp et al., 2007
  - Anderson and Pandy, 1999
- Start to think about topics for your research project and begin to form teams of two
- Be sure to check the course website: http://rrg.utk.edu/resources/BME599