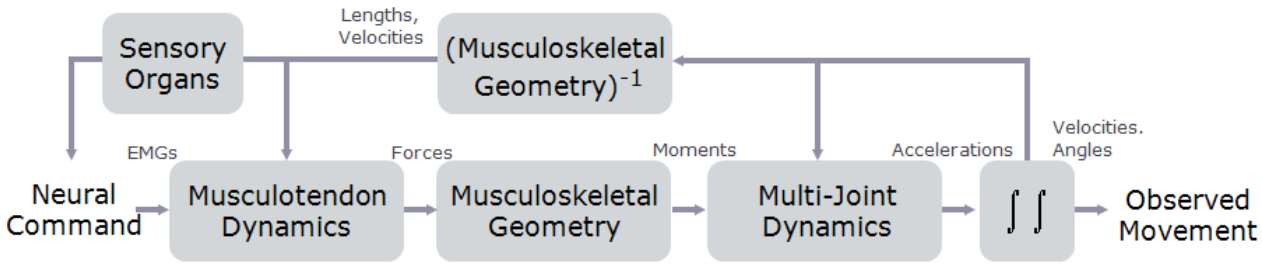
SIMULATION LABS
BME 599 ~ Modeling & Simulation of Human Movement

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 these moments, multi-joint dynamics determines accelerations and ground reactions producing the movement that we observe. The way the human body moves affects subsequent neural commands to adjust the movement, and it affects the length and velocity of the muscle-tendon, the direction of muscle forces and moment arms, and the resulting dynamics of the multi-body system.

Simulation lab assignments will develop mathematical models for each component involved in the production of voluntary movement. In addition, these models will be implemented in simulation software and analyzed to gain insight into movement biomechanics. Each lab will grow in complexity to build your modeling and simulation capabilities.

While you are encouraged to work together on lab assignments, copying of assignments is not permitted. After figuring out with others how to complete the assignment, each student must work individually to create and run his or her own computer code.

Simulation Lab 1: Dynamic Simulation of Jumping

The purpose of this lab is to give you experience with a complex, dynamic model of the human musculoskeletal system. In the course of this lab, you will:

- Determine excitations to produce a jump
- Study actions produced by muscles
- Compare simulation to experimental data
- Quantify the magnitude of the hip forces
- Examine quad force over simulation

Simulation Lab 2: Modeling Musculoskeletal Geometry

The purpose of this lab is to give you experience building and evaluating models of musculoskeletal geometry which will later be used for developing muscle-actuated, forward dynamic simulations of movement. In the course of this lab, you will:

- Visualize 3D anatomy of selected structures of the lower limb
- Create a model of a muscle path
- Create models of simple and complex joints
- Introduce wrapping surfaces to represent muscles
- Assess accuracy of model by comparison with experimental data
- Describe analyses you could perform with this type of model.

Simulation Lab 3: Torque-driven Simulation of Swing

The purpose of this lab is to give you experience using OpenSim to generate and numerically solve differential equations of motion for a biomechanical system. In the course of this lab, you will:

- Use OpenSim to model dynamics and generate equations of motion
- Discover passive dynamics of swing
- Explore contributions of joint torques
- Examine causes of stiff-knee gait

Simulation Lab 4: Dynamic Modeling and Simulation of Muscle-Tendon

The purpose of this lab is to give you experience using and modifying models of muscle-tendon dynamic contractions during a simulation. In the course of this lab, you will:

- Generate differential equations that describe muscle dynamics
- Use OpenSim to simulate dynamics
- Analyze the effects of model parameters on actuator performance

Simulation Lab 5: Muscle-actuated Simulation of Swing

The purpose of this lab is to give you in-depth experience combining the previous three labs together to produce a muscle-actuated forward dynamic simulation of movement in preparation for your project. In the course of this lab, you will:

- Use OpenSim to generate equations of motion
- Prescribe muscle excitations to generate coordinated movement
- Study effects of abnormal control