Instructions

Find your slide:
- Scroll through the slides and find your project title.

Edit your slides:
- Add text, photos and/or embed youtube videos.
- Insert Videos from Youtube

3 minute presentation, 1 minute questions:
- You will present in the current order of the slides. Everyone is looking forward to seeing your work but you will have three minutes, so be mindful.

Project Title

- Showcase your results by sharing:
  - Video(s) of your simulations
  - Demo your models or simulations
  - Figures demonstrating cool results
  - Blooper videos

Motivation:
Understand the effects of muscle forces on cartilage contact mechanics in patient specific models of the hip and ankle.

Workshop Goals:
1. Develop realistic joint reaction analysis of the hip
2. Incorporate subject specific bones and muscle lines of action
3. Develop custom ankle joint model
   - Add ligament/soft tissue constraints
   - Define coupled DOF

Toward Incorporation of Patient-Specific Arthrokinematics in OpenSim Musculoskeletal Models of the Lower Limb
Andrew Anderson, Penny Atkins, Nic Fiorentino, Jen Nichols, Koren Roach

Dual Fluoroscopy Images
-180° speed

Incorporating Patient-Specific Parameters

Hip Joint Reaction Force
Dual Fluoroscopy vs. Vicon Results

Normalized Joint Reaction Force over Two Gait Cycles

- z hip
- v hip
- p hip
- pLS
- pl swim
- pl run
Incorporating Soft Tissue Constraints in a 6 DOF Ankle Joint Complex: A Work in Progress

Lessons Learned:
- Static optimization runs with our 6 DOF model
- Path springs appear to be more stable than ligaments
- Bushing forces are a viable alternative to path springs
- Identified peroneal muscles as a potential "problem" area

Troubleshooting Ligament-Muscle Interactions in Static Optimization

Adding PathSprings

Simultaneous Prediction of Knee Ligament Loads, Muscle Forces and Cartilage Contact Pressure during Movement

Big Picture Motivation:
- Investigate impact of ligament injury and subsequent treatment on knee motion and contact pressures
- Share our model with biomechanics community

Workshop Goal:
- Implement new ligament model
- Export pressure information
- Run passive forward simulation and compare to current framework

Workshop Progress:
- Implement new ligament model
  - UWLigament Plugin
    - Based on Blankevoort and Huiskes, 1991
- Export pressure information
  - Did not work on this; it's going to be part of updated contact in new Opensim 4.0
- Run passive forward simulation and compare to current framework
  - Passive simulations run with updated ligament model

Still to do:
- Verify ligament model

Workshop Road Blocks:
- Contact detection is super slow → must make very coarse meshes to run
  - Our prior work indicates that pressure results are sensitive to mesh density, and our original meshes are on the low end of acceptable.
Simultaneous Prediction of Knee Ligament Loads, Muscle Forces and Cartilage Contact Pressure during Movement

1. Model
   - Rigid Tendon
   - ArtiSynth values
   - Passive Forces

2. Joints
   Background
   - improving postural stability
   - co-activation and joint stiffness

Simulating the effect of muscle co-activation on postural stability
Workshop Goal
- Problem: Static-optimization minimizes co-activation
- Plan: Achieve co-activation by optimizing joint stiffness

Changes in muscle-tendon dynamics as a result of work input and torque support with an ankle exoskeleton

Rachel Jackson

Big Picture Motivation: Study changes in plantarflexor muscle-tendon dynamics under different ankle exoskeleton behaviors

Approach: Kinematics and EMG driven simulation (Based on Arnold and Farris)

Changes in muscle-tendon dynamics as a result of work input and torque support with an ankle exoskeleton

- Comparison of inverse dynamics and forward dynamics ankle moments

- To Do:
  - Change over to Arnold model
  - Optimize muscle activation/deactivation time constants
  - Normalization of EMG - what is an excitation of 1?
  - Run for remaining conditions and subjects
  - Analyze changes in muscle-tendon dynamics (and muscle energy consumption eventually?)

Adaptation of the musculoskeletal system after stroke and its impact on resting arm posture and passive joint stiffness

Christa Nelson, PT, DPT
PhD advisors: Jules Dewald, PhD and Wendy Murray, PhD

Big picture motivation: Utilize dynamic upper extremity model to investigate mechanisms of musculoskeletal adaptation after stroke.

Workshop goals:
- Implement experimental torque-angle data into model to investigate changes in resting arm posture.
- Create workflow for automating simulations as well as running sensitivity analyses.

More flexed elbow position in paretic arm
On the Optimization of Bicycle Ergonomics

Mathieu Domalain & Mathieu Menard

Well constrained activations....

Comparison iliotibial Band - Femur force between 2 sitting positions

Total Muscle Metabolics

Forward dynamic modelling to determine the neuromuscular limitations to stumble recovery potential

1. Tell us about you:
   Grant Trewartha (Bath) & David Graham (UNE / Griffith)

2. Big Picture Motivation:
   To understand neuromuscular limitations to balance recovery and the effect of balance training interventions

3. Workshop Goal:
   a. Integrate a contact model into the foot-ground interface
      - CMC solution of 1 trial
      - Contact spheres from landing model, additional sphere @ hallux
      - Bushings at support leg ankle & knee joint
   b. Perform our first forward simulations
      - FD solution looks kind of respectable

4. Future Work:
   - Optimise contact parameters (lean-release & stumbles)
   - Investigate effect of motor control strategies on recovery potential
Forward dynamic modelling to determine the neuromuscular limitations to stumble recovery potential

Determining hip joint reaction forces with subject-specific musculoskeletal models

**Iain Hannah**
INSIGNEO Institute for in silico Medicine, University of Sheffield, United Kingdom.

**Workshop Progress**
- Matlab code written for batch processing OpenSim pipeline
  - Muscle origin, insertion and via points
  - Joint axes
  - Single/multi-segment foot loading
  - Maximum isometric force
- IK, ID, SO, Analyze
- Multiple subjects and trials
- Allows model sensitivity to be investigated

**Next Steps**
- Implement with OpenSim API

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Determining hip joint reaction forces with subject-specific musculoskeletal models

Next Steps
- Implement with OpenSim API

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Matlab API for real-time closed loop OpenSim simulations

Val Gritsenko, Sergiy Yakovenko, Drew Goodman, Anton Sobinov, Kirill Tuntevski, Russell Hardesty, Adam Chivers
(Neural Engineering and Rehabilitation Laboratories, WVU)

**Real-time Optimizations**
- Running IK, ID in Matlab with close to RT performance
- Menard muscle model with rigid tendon
- Replacement of complex wrapping geometry with cylinders
- Replacement of moving via points
- Compiling OpenSim for OSX (OpenSim Simbody, dynamic libraries are still not linking -> no Matlab)

Saule et al., Murray (2014)
Daniel Krüger
Engineering Design, University of Erlangen-Nuremberg, Germany
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Big Picture Motivation
To use biomechanical stress as an ergonomic assessment criterion.

Workshop Goal
Find an optimal resistance profile for the leg extender:
\[ \text{maximize training efficiency} \]
\[ \text{minimize the risk of injury} \]

Objective: preserve the amount of muscle effort while reducing tibiofemoral shear and patellofemoral compression

Findings
- potential to relieve the knee joint
- only small impact on muscular effort
- paradox increase of shear forces \[ \Rightarrow \] quadriceps femoris protects the knee!

Future: Find an optimal tibia-lever contact point in order to reduce tibiofemoral forces as well.

Matthew Millard, Katja Mombaur
University of Heidelberg ORB

Goals
1. Implement a rolling-without-slipping cylinder-plane constraint in Simbody*
2. Assemble the joint using the assembler
3. Check that energy is conserved
4. Extract the constraint forces
5. Implement a constraint switch

Design optimization of a leg extension training machine

A rigid holonomic foot-ground joint for fast & accurate predictive simulations
Achieved

1. Implement a rolling-without-slipping cylinder-plane constraint in Simbody®
2. Assemble the joint using the assembler
3. Check that energy is conserved
4. Extract the constraint forces
5. Implement a constraint switch

The Gravity Loading Countermeasure Skinsuit

1. Tell us about you:
   - Dustin Kendrick, Man-Vehicle Lab and Harvard-MIT Bioastronautics Program, MIT
2. Big Picture Motivation:
   - To develop a countermeasure garment that can be used to provide axial body loading similar to 1-g loading on earth, in order to augment existing spaceflight countermeasures.
   - Modeling provides insight into in-vivo loading and can inform design decisions
3. Workshop Goal:
   1. Determine the effects of changing material properties on suit loading.
   2. Determine the loads the suit puts on the body during more complex, multi-joint motions, such as squats

The Gravity Loading Countermeasure Skinsuit

Accomplishments:
1. Modified model to accommodate wider range of material stiffness
2. Performed basic analyses of multi-joint movement
3. Learned some additional capabilities (force reporter, CMC, etc)

Proprioceptive modeling of the peripheral nervous system as an extension to OpenSim

Motivation
Modeling and quantification of the peripheral nervous system will provide useful information on quantities that can’t be directly measured and have a direct impact on the motor behavior.

Goals
- Correctly translate alternative models from the literature to OpenSim.
- Use optimization techniques to calibrate some parameters of the model, based on experimental kinematics or other means.
- Forward simulation of the patella reflex to predict the internal signals (test cases).

Thank you Scott, James, Matt, Sherm, Ajay, Tom, Ayman, Soha, Apoorva, Jenny, Carmichael, and Diane for an awesome workshop!
Proprioceptive modeling of the peripheral nervous system as an extension to OpenSim

Problems
- Lack of experimental data
- Overfitting of the model
- Modeling assumptions

Contribution
- Prove OpenSim can be used for model composition as an alternative to Matlab’s Simulink
- First attempt to couple all sensory receptors in the coordination of muscle activation

Future Work
- Enhance validation with EMG
- Alternative ways of parameter estimation

Development of a Dynamic Walking Test Bed to Explore Principles of Locomotor Learning

Key questions
- To what extent can passive mechanics explain kinematic adaptations to walking on a split-belt treadmill?
- Can a simple model with limit cycle dynamics and no control exhibit “learning”?  

Long-term Goal
- Test hypotheses about the role of energetics and stability during locomotor adaptation

Workshop Goals
- Generate a state-dependent controller to enable level-ground walking in simple, passive walker
- Determine how to integrate the controller and model in Matlab

What we accomplished
1. Created basic visualizer in Matlab for previously-optimized passive walker

Next steps
- Actuate model using Matlab-based, state-dependent controller
- Add 2nd platform to simulate split-belt treadmill
- Optimize actuated model and compare behavior to experimental observations

1. Implemented actuated slider joint with PD controller for virtual treadmill
   a. Led to late-night realization that we can use Matlab for state-dependent control
2. Ran first (failed) optimizations for passive dynamic treadmill walking on a slope
An OpenSim modeling framework to estimate non-idealities in human-exoskeleton interaction

**Research Goal**

- **Optimize spaceflight exercise countermeasures to reproduce stimulus similar to 1-g Squat in terms of effective bone and muscle loading.**

**Workshop Goals**

1. **Determine the bone and muscle loading during squat in 1g**
   a. Acceptable results from Inverse Kinematics
   b. Acceptable results from Inverse Dynamics especially for pelvis residual forces along y direction, pelvis tilt, hip rotation etc.
   c. Address model drifting after RRA
   d. Computed Muscle Control and Analyze
   e. Bone and Muscle Forces
2. **Determine bone and muscle loading during squat in microgravity conditions**
   a. Simulating microgravity in OpenSim

**Estimation of Bone and Muscle forces during squat exercise for 1g and microgravity conditions**

Satya Sri M, Graduate Student
Human Systems & Simulation Lab (HSSL)
Department of Aerospace & Engineering Mechanics, University of Cincinnati

**Research Goal**

- Optimize spaceflight exercise countermeasures to reproduce stimulus similar to 1-g Squat in terms of effective bone and muscle loading.

**Workshop Goals**

1. **Determine the bone and muscle loading during squat in 1g**
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   d. Computed Muscle Control and Analyze
   e. Bone and Muscle Forces
2. **Determine bone and muscle loading during squat in microgravity conditions**
   a. Simulating microgravity in OpenSim
Estimation of Bone and Muscle forces during squat exercise for 1g and microgravity conditions

★ Squat Simulation in 1g Environment
- IK results show knee angles ranging from 0–75 degrees and hip flexion ranges from -6–30 degrees
- Successful RRA run

Reflections
- Scaling the model to accuracy up to 1cm of rms error and maximum error of 4cm is highly important for further steps
- What does bone forces mean? Are they joint reaction forces or the intersegmental forces?
  Ans: Joint reaction forces

Simulating Squat in hypo-gravity Environment
- Changed the gravity component in .osim file
- Squat in Spa

Can FES rowing mediate bone loss in people with spinal cord injuries?
Becky Lambach, Musculoskeletal Laboratory, VA Palo Alto Health care System

Motivation:
- Significant bone loss after spinal cord injury
- Functional Electrical Stimulation (FES) Rowing:
  - Stimulation of quadriceps and hamstrings
  - Full-body workout: cardiovascular benefits
  - Case study has shown bone loss reversal in one individual

Modeling goal: determine internal forces imposed on the lower extremities during FES rowing

Workshop Goals:
- Add a seat to the current model
- Modify joints between body and seat, seat and ground

Future Work (goals 3 and 4):
- Explore a CMC pathway for estimation of muscle forces
- Tune CMC constraints to control muscle activation
Motivation
- Lokomat do not allow for tracking kinematic and kinetics using standard methods like stereophotogrammetric systems combined with force plates
- It also greatly limits the access to many muscles of the leg for EMG recordings
- Being able to estimate as much parameters as possible would greatly help tracking improvements during therapy

Workshop Goals
- To develop a platform that would allow us to estimate additional kinematics, kinetics and controls during Lokomat walking from Lokomat data and a limited number of EMGs
  - Estimate muscle forces
  - Estimate muscle activity

Alessandra Scarton (ascarton@partners.org) and Giacomo Severini (gseverini@partners.org)
The role of Neck and Trunk Muscles Activation during Sport Impacts

1. Dario Cazzola:
   Dept for Health, University of Bath, UK

2. Big Picture Motivation:
   - Analysis of the cervical spine injury mechanisms during sport impacts:
     - Any optimal neck muscles activation strategy?
     - Hyperflexion or buckling mechanism?

3. Workshop Goal:
   - Optimise RRA in presence of high & multiple external loads
     - Analysis of individual neck muscles activation (CMC)
     - Sensitivity analysis - (extra load applied on the head)

Future Work:
- RRA to optimise Force point of app
- Mass distribution (initial Mz moment?)

Force Residuals: 5 to 18%
Moment Residuals: 100 N.m (???)
Mz = 250 N.m