# Katelyn Cahill-Thompson Workshop Results

## OpenSim Workshop August 2011

# Progress on Primary Goals

## Initial Goal 1: Streamline process of scaling, finding and muscle lengths from a static pose, plotting muscle lengths

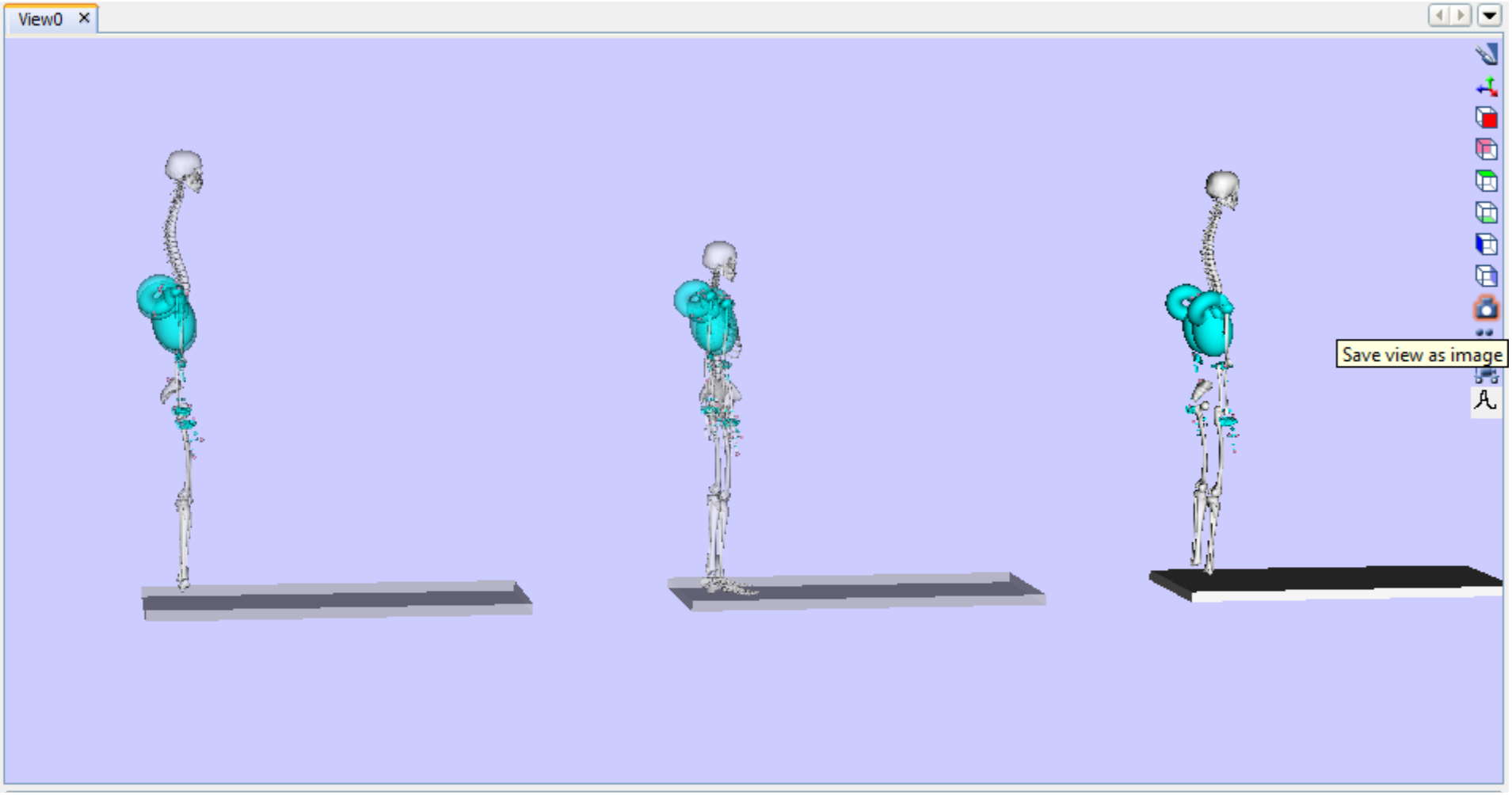
-For the first time, I was able to produce Scale Setup .xml files with Matlab

-Automated creation of a large batch of Scale Setup files with concise Matlab code

-Within the same code, ran scale.exe in Matlab for the entire batch

-Produced…

# ...This



# Progress on Primary Goals

**Initial Goal 1: Streamline process of scaling, finding and muscle lengths from a static pose, plotting muscle lengths**

-Agony—where was my error?

-Bug!

-Bug avoided!

-Onward march—automated edit of newly-produced models to unlock degrees of freedom

-Automated batch processes: Setup to tool

Scale.xml → Scale.exe → Edit model files → IK.xml → IK.exe → MuscleAnalysis.xml → MuscleAnalysis.exe → Data Presentation

# Progress on Primary Goals

**Initial Goal 2: Increase my proficiency and especially *efficiency,* in terms of time to process, in OpenSim.**

-Problem: constraints slowing ik.exe to ~4 hours run time for 5 sec motion

-Cause identification: excessive constraints

-Long term solution: edit model

-Short term solution: OpenSim 2.3.2 brings runtime to 8 minutes!

-Problem: Many patients, many trials, a lot of time and tedium

-Solution: excellent new resources and skills for batch processes and automated solutions

# Progress on Primary Goals

**Initial Goal 3: Produce one Matlab script to batch process (1) .trc motion file and (2) generic model with markers, producing (3) muscle analysis.**

-I started having already created Matlab files to produce and present muscle analysis data from ik motion files

-Now, I have automated production of xml files: scaling setup files, models, and model-file editing in two files

-I have the knowledge foundation I need to continue with this process for ik setup files and muscle analysis files

-More elegant methods for running OpenSim tools from Matlab

# Summary of Progress

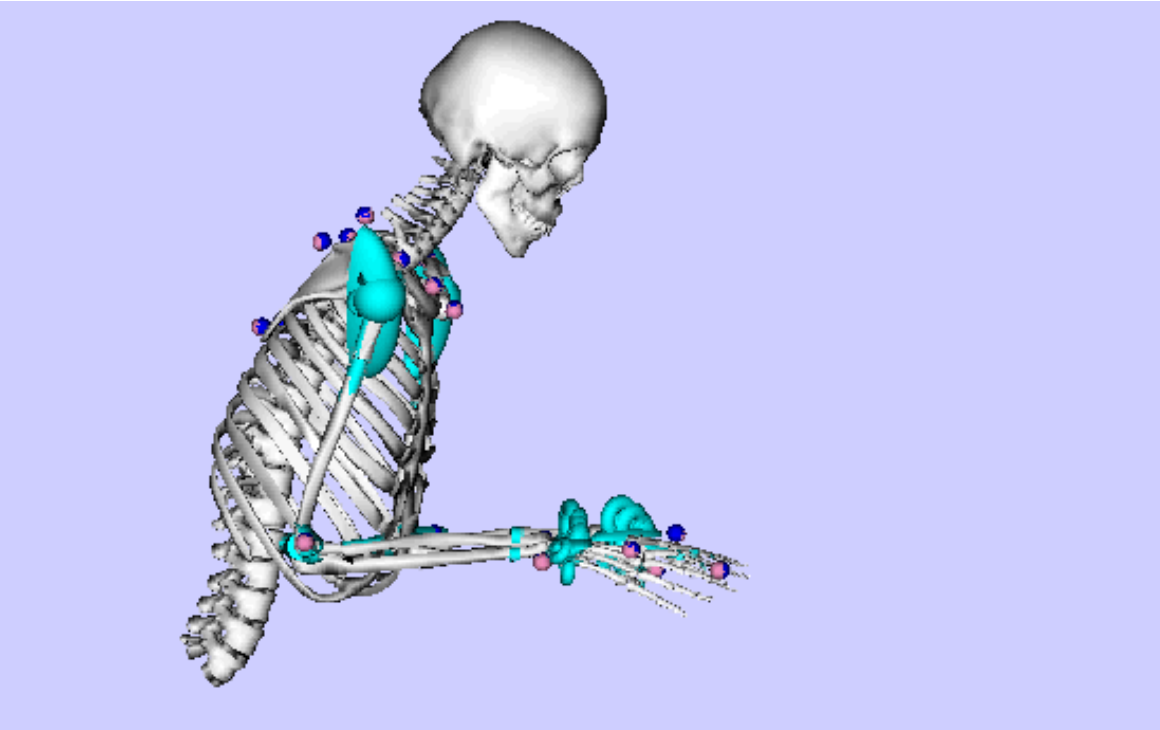
-For the first time, I was able to create and edit xml files from Matlab

-Did so in a large-scale, automated, elegant fashion, incorporating OpenSim tools

-Sidestepped dinosaur bug

-Increased ik runtime efficiency by 30 times

# THANK YOU! OpenSim team!



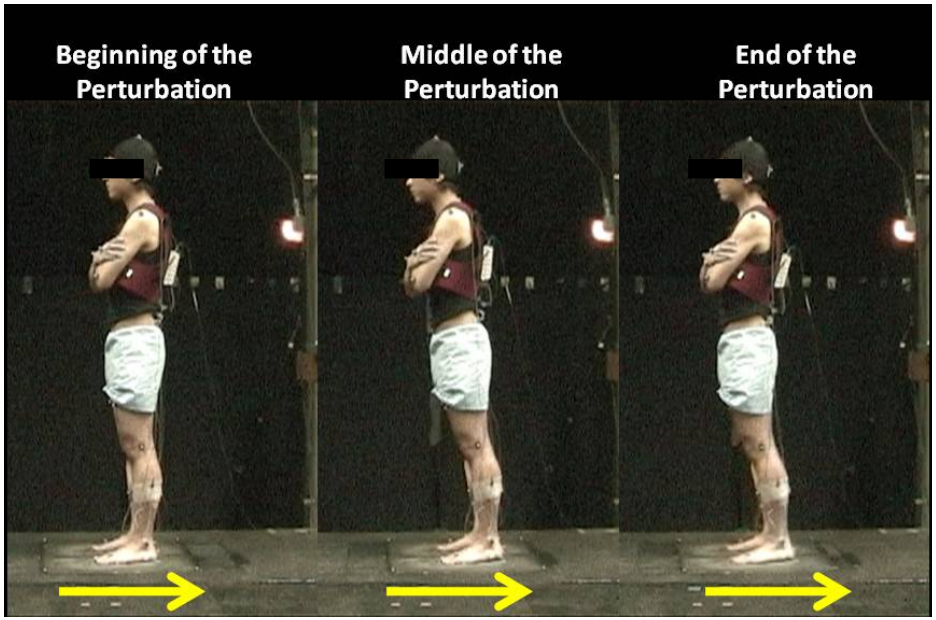
# Masa Fujimoto's Progress

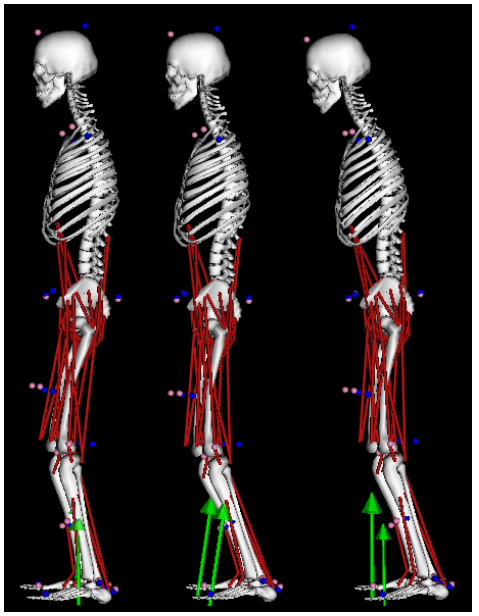
## OpenSim Workshop August 2011

# Goal to be Accomplished

**How changes in perturbation speed would affect estimated muscle activations of plantarflexor/dorsiflexor muscles?**

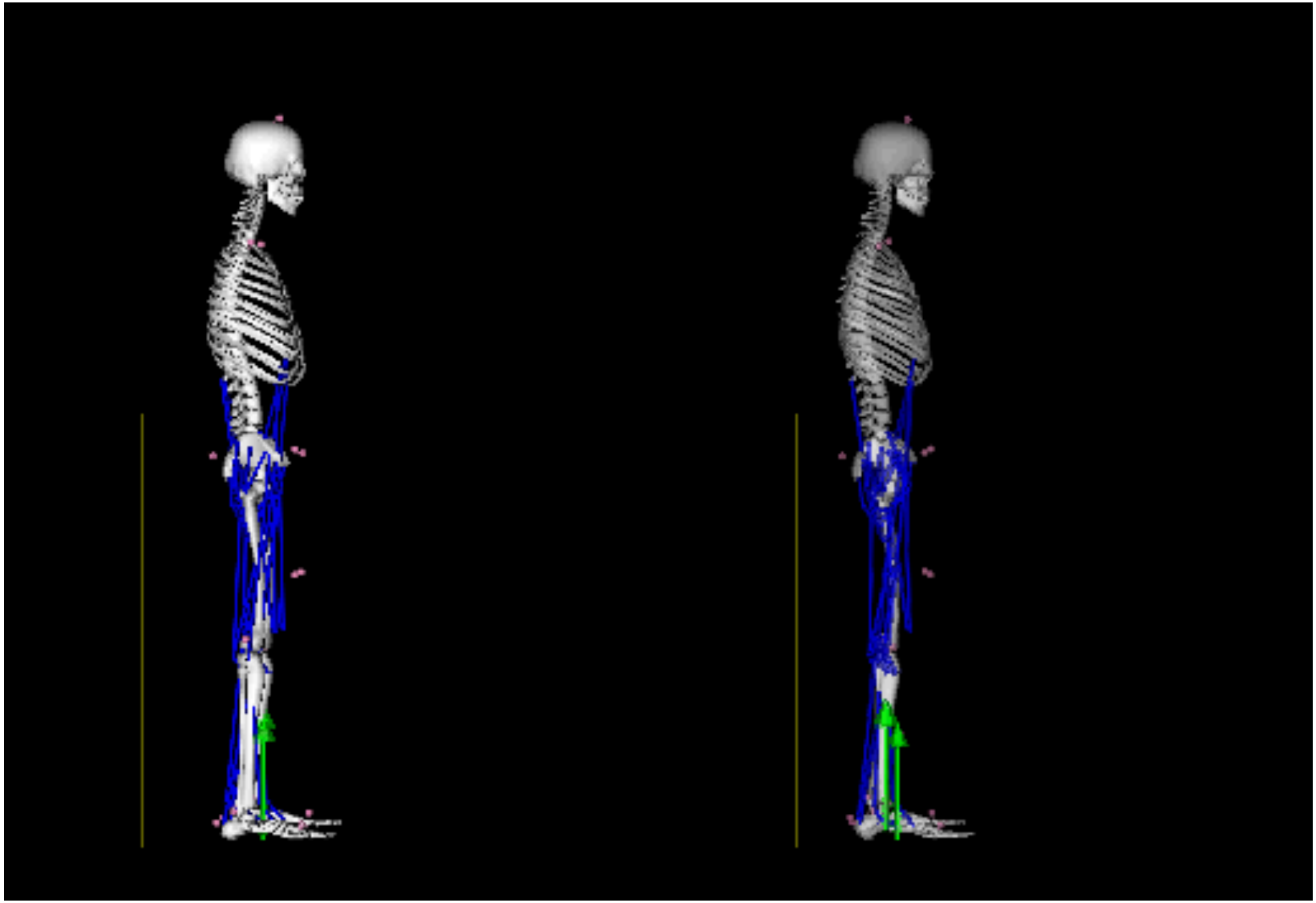
- Kinematics of the body movement during stance perturbations with the speed of 30, 50, 70cm/s, GRFs
- OpenSim gait2354 scaled model that tracks kinematics and GRFs



- Challenge was how to successfully achieve RRA and CMC
- Goal: finish CMC to obtain effects of perturbation speed on muscle control
- Able to finish CMC for the speeds of 30cm/s and 70cm/s

# IK trials

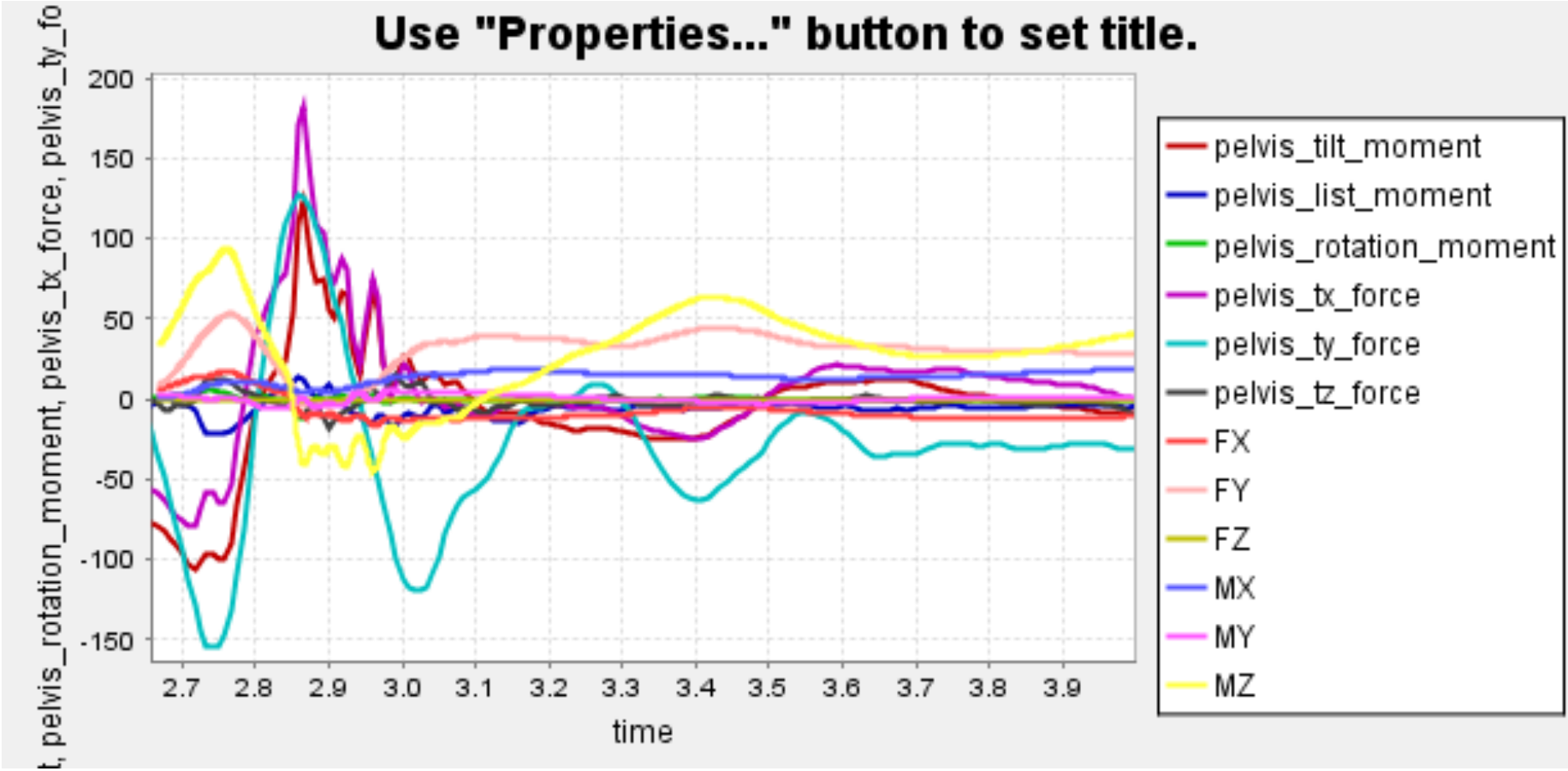


30cm/s

70cm/s

# Inverse Dynamics and RRA

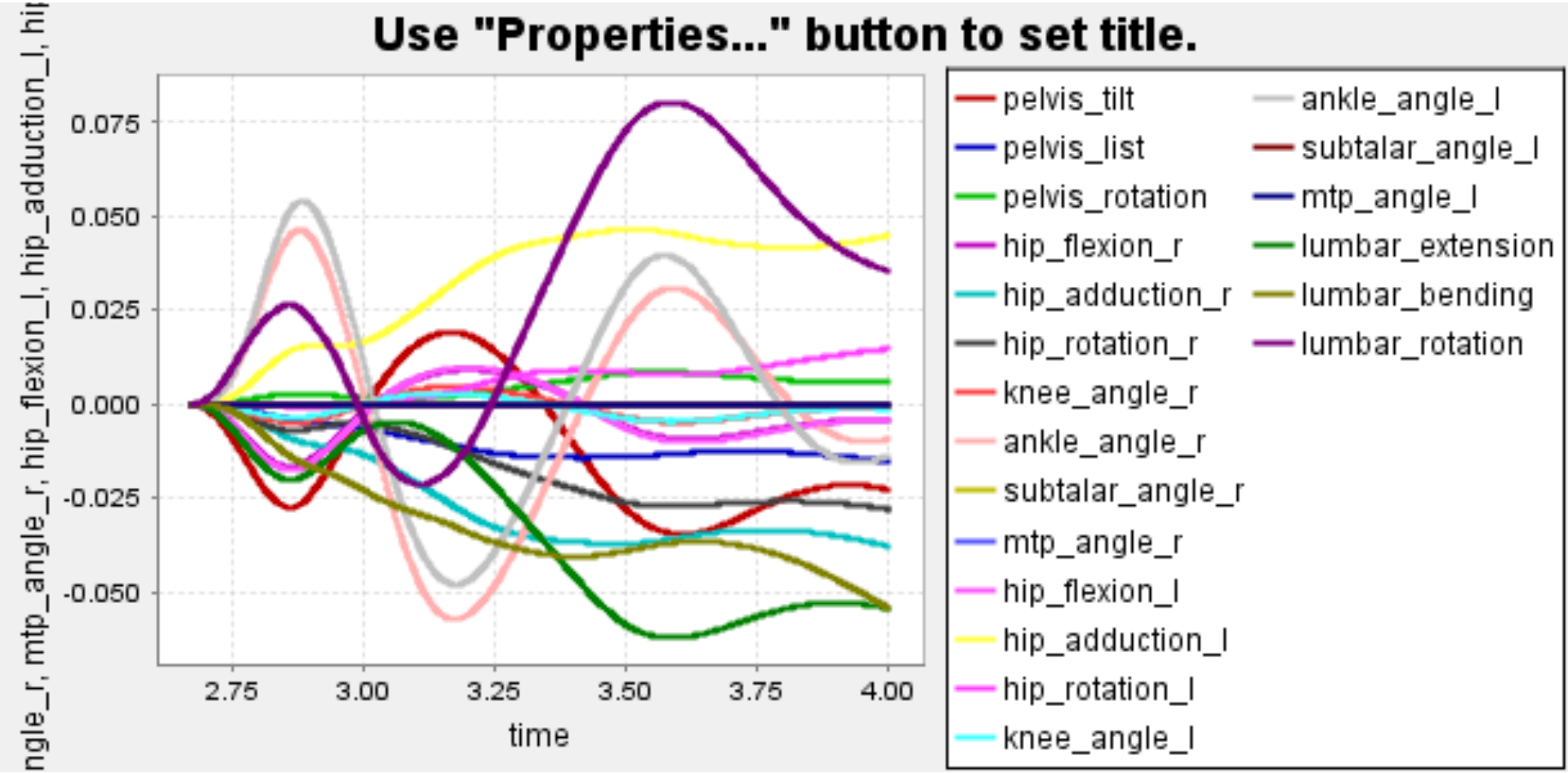
Residual forces and moments before and after RRA




Fy(light blue&pink): reduced it by ~70%
Mz(red&yellow): not much difference

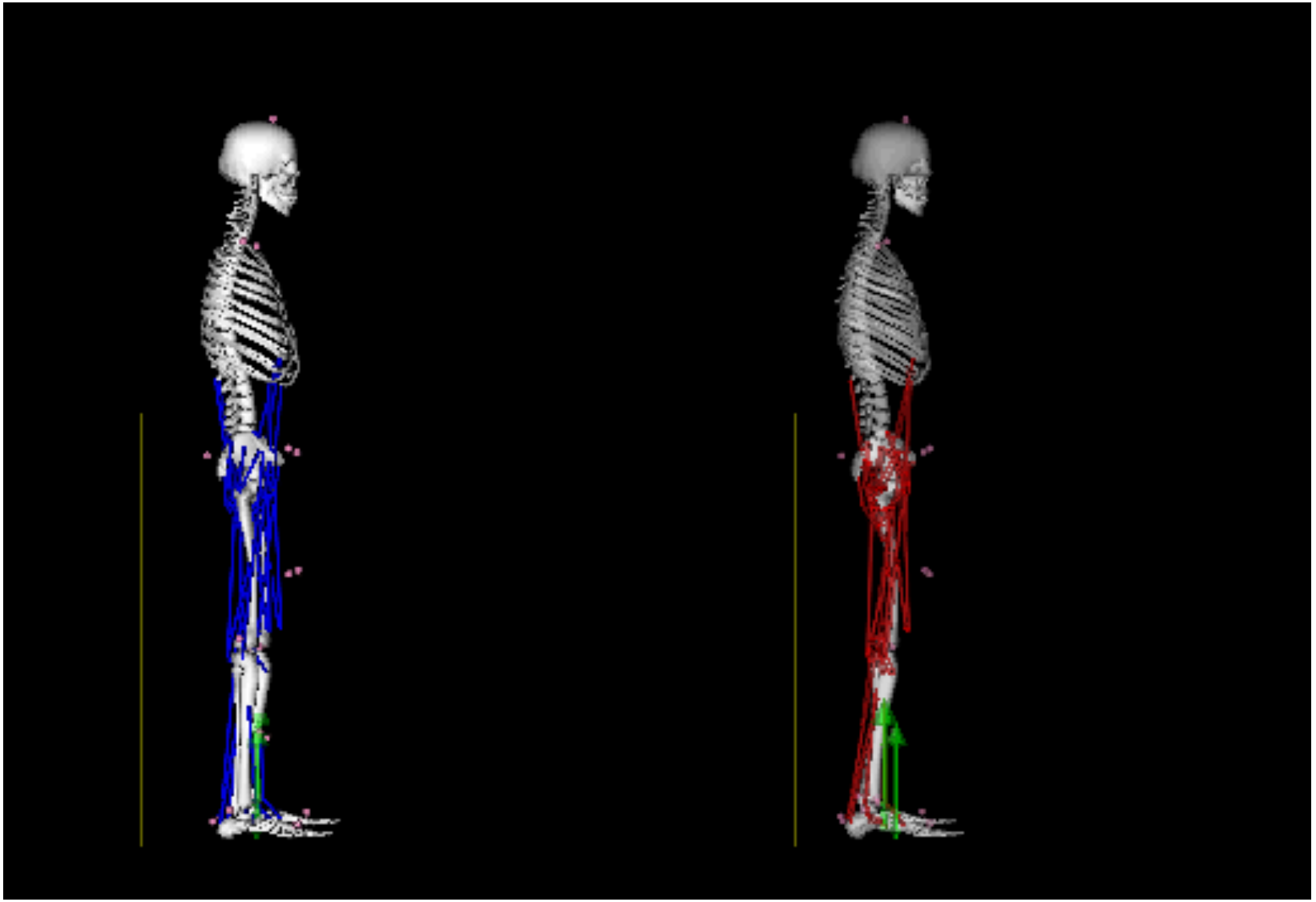
# Inverse Dynamics and RRA

Errors




Within ~4deg

# IK trial and RRA



IK trial

RRA result

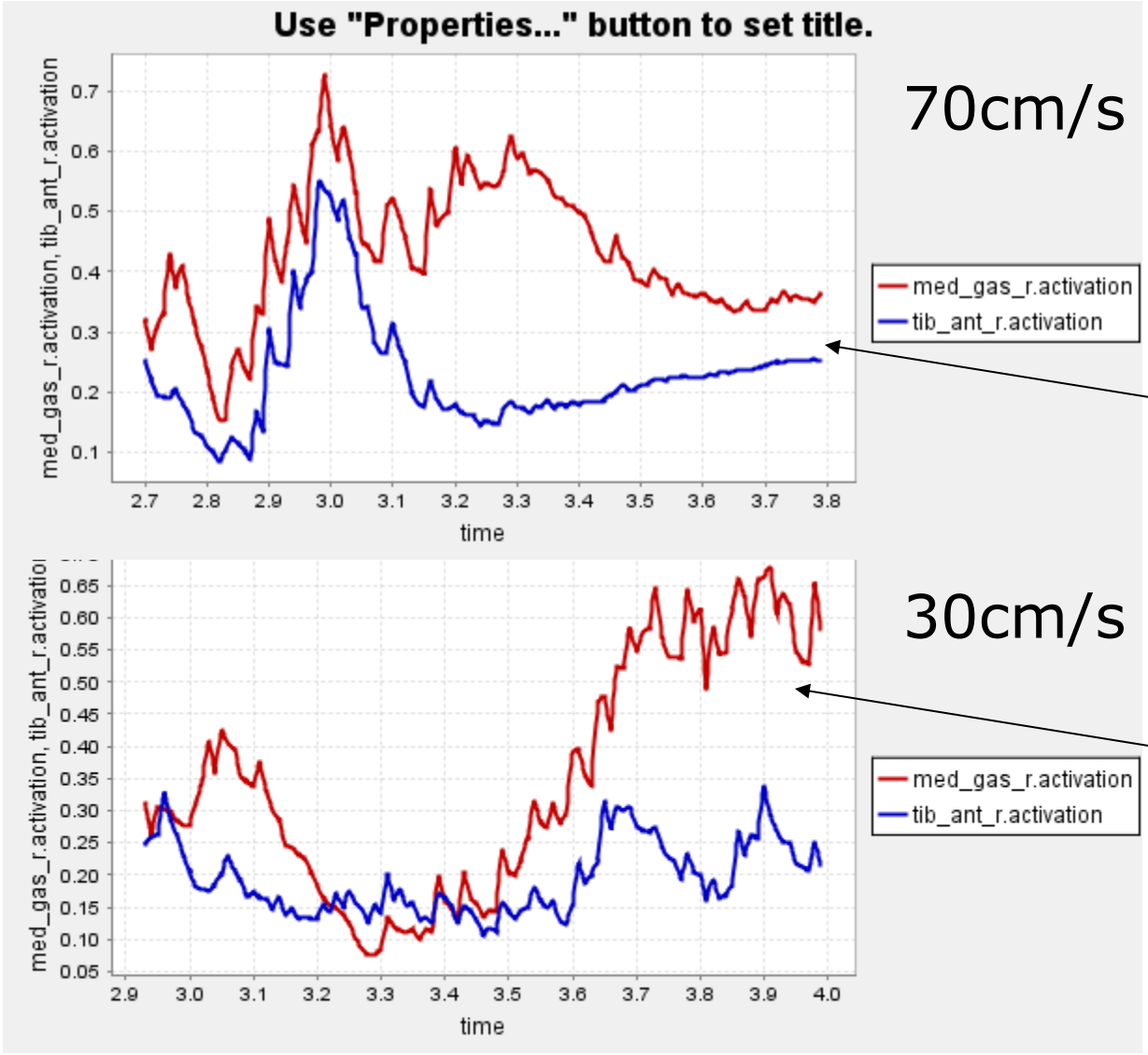
## CMC

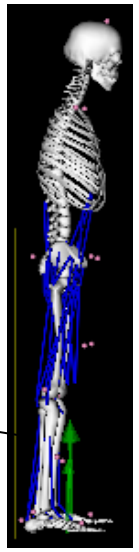
- Failed with default optimizer with fast target, even with a large optimal force for residual and reserve actuators.

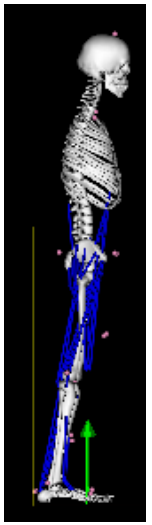
- Optimizer: ipopt -> cfsqp
- Optimization target: fast -> slow

# Muscle activation levels

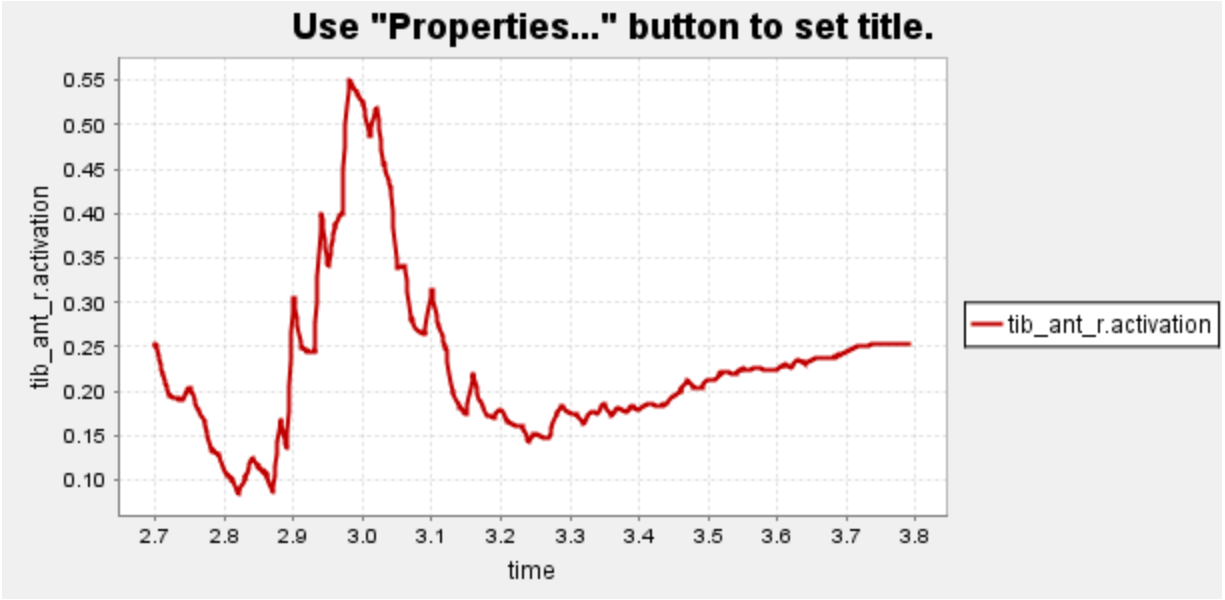
- Looked at Tibialis Anterior and medial Gastrocnemius

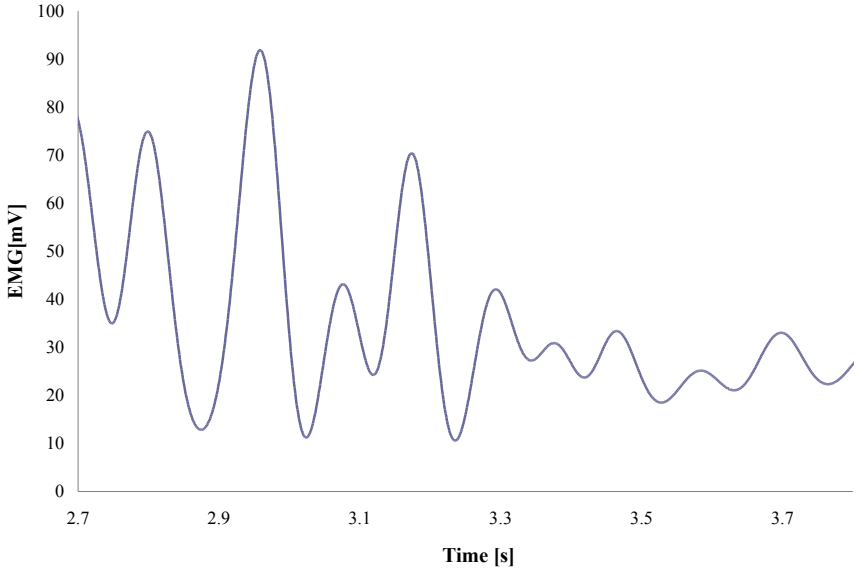




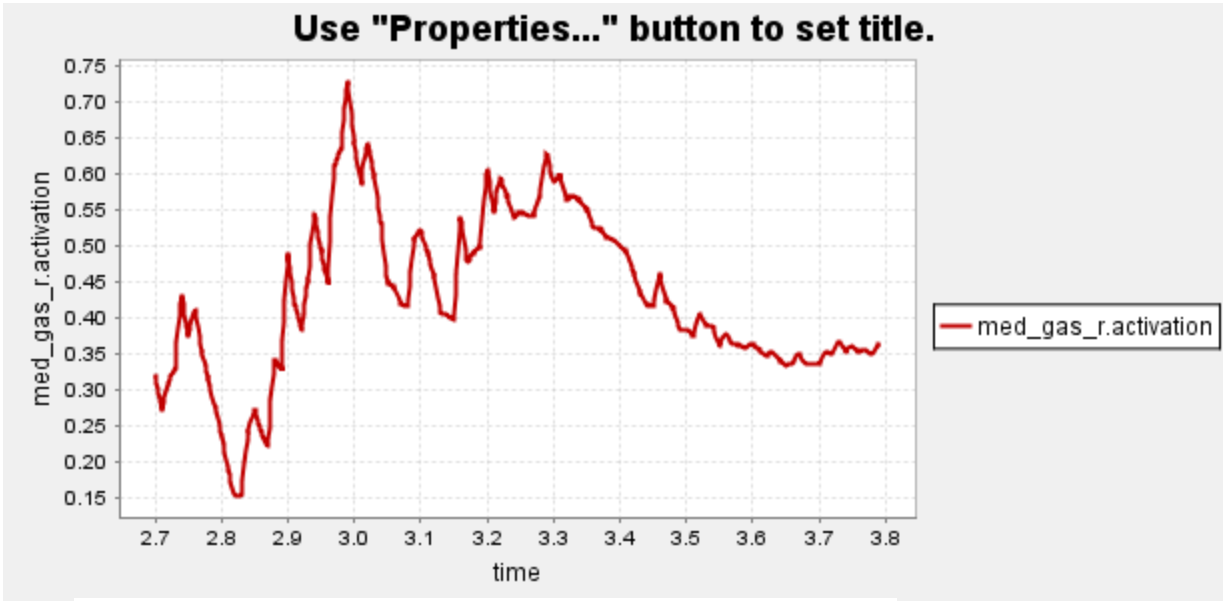
# EMG data

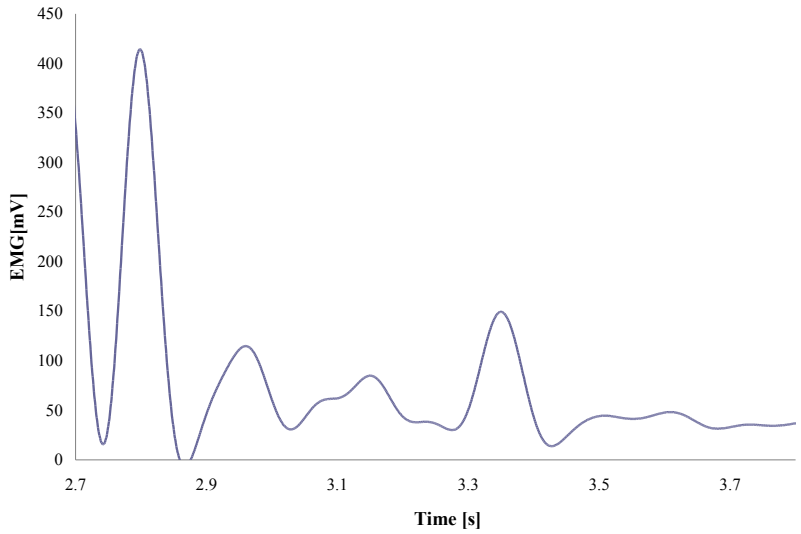



Tibialis Anterior

# EMG data




Gastrocnemius

## Future Plans

- Play with RRA and CMC

- Compare muscle activation levels with recorded EMG data

- Compare muscle controls between stepping and non-stepping responses.

- Change muscle activation levels and run Forward dynamics to see if it results in unstable posture

- Induced Acceleration Analysis

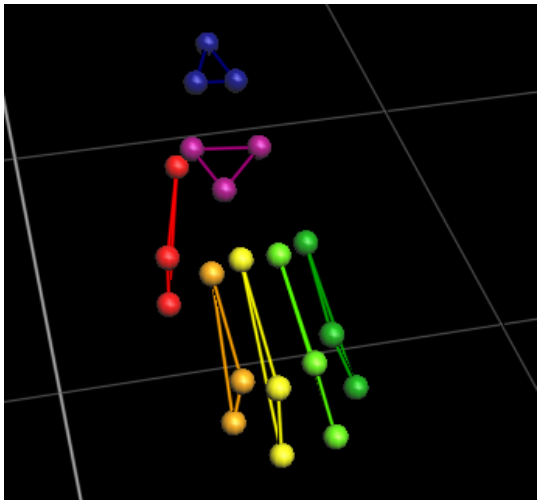
# Alexander Rajan - Results

OpenSim Workshop August 2011

# Primary Goals to be Accomplished

4. **How does cortical activity in M1 and S1 correlate with the muscles and joints involved in grasping behaviors?**

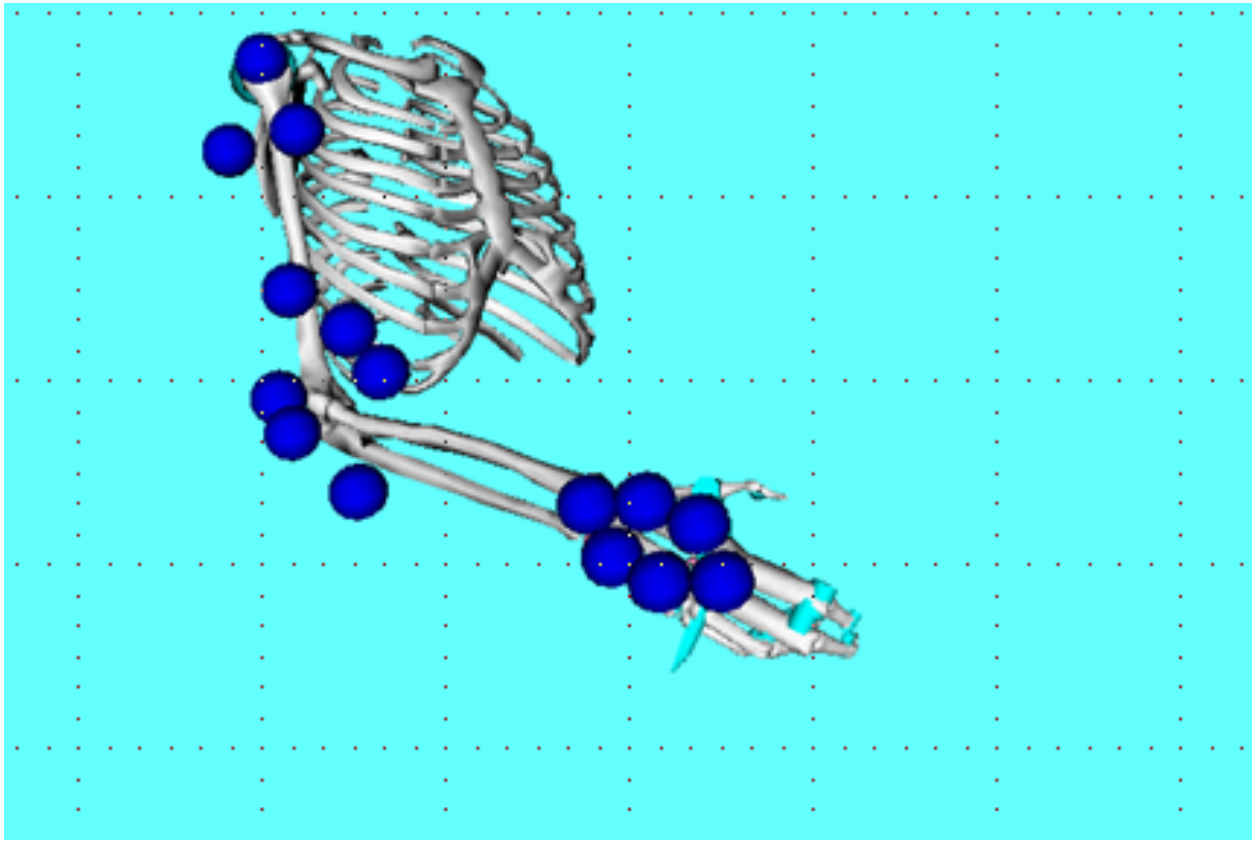
   - I would like to simulate muscle activation given kinematic data and the musculoskeletal wrist/ hand model
   - Bringing: kinematic data from a non-human primate



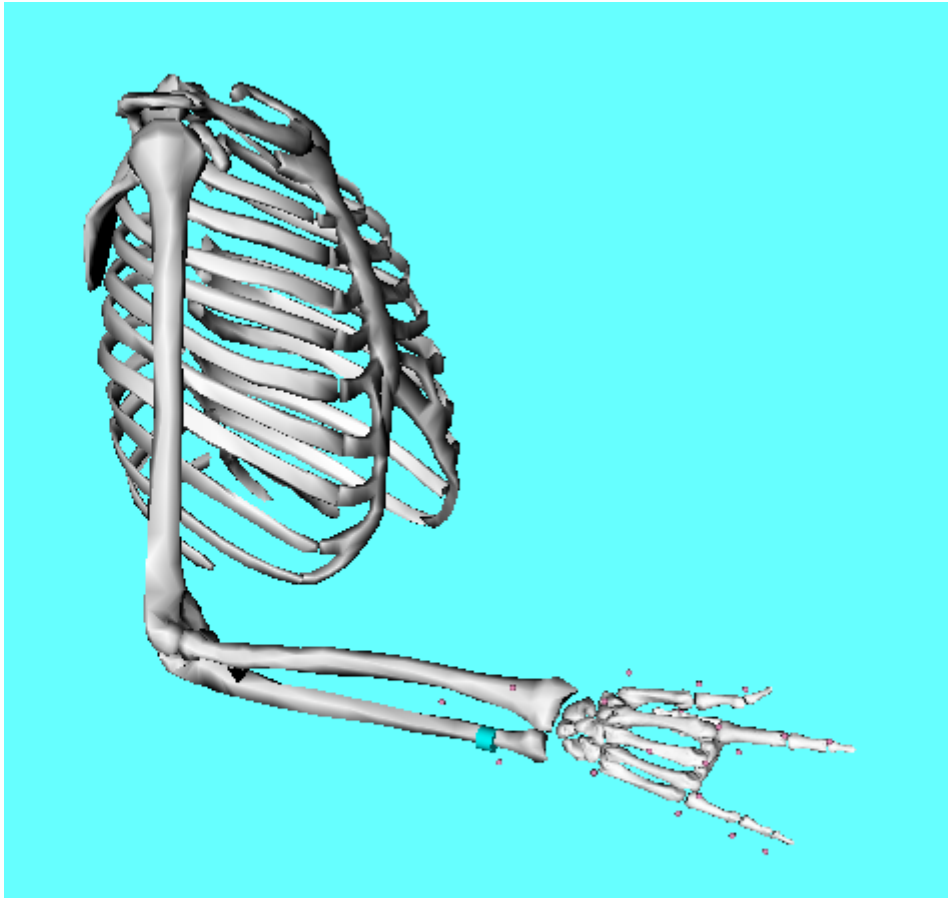
   - Challenge: Setting up a robust model to reliably extract kinematics and muscle activations
   - Plan to have a working model and be able to fit kinematic data to it

# Play “Wheel” video

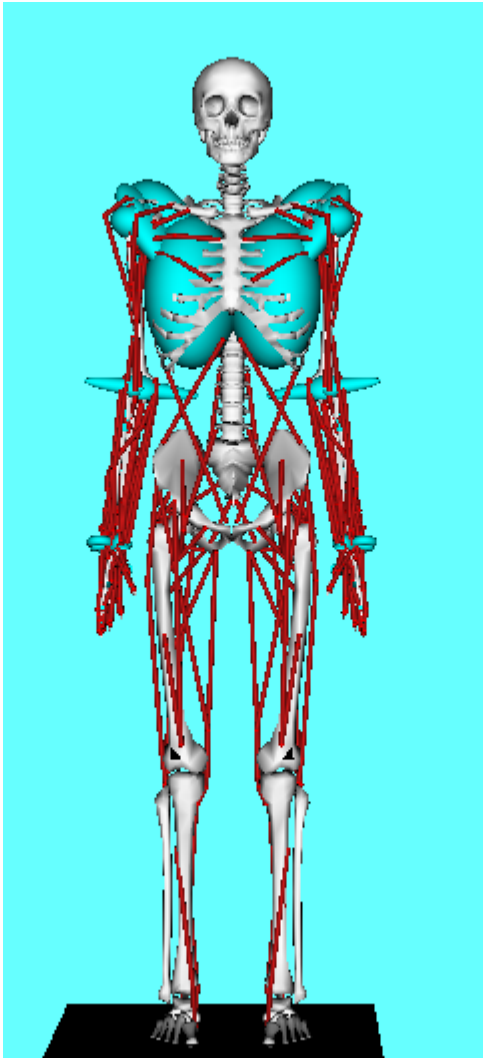
Rigid hand, IK fits experimental markers poorly



# Day 1 Model

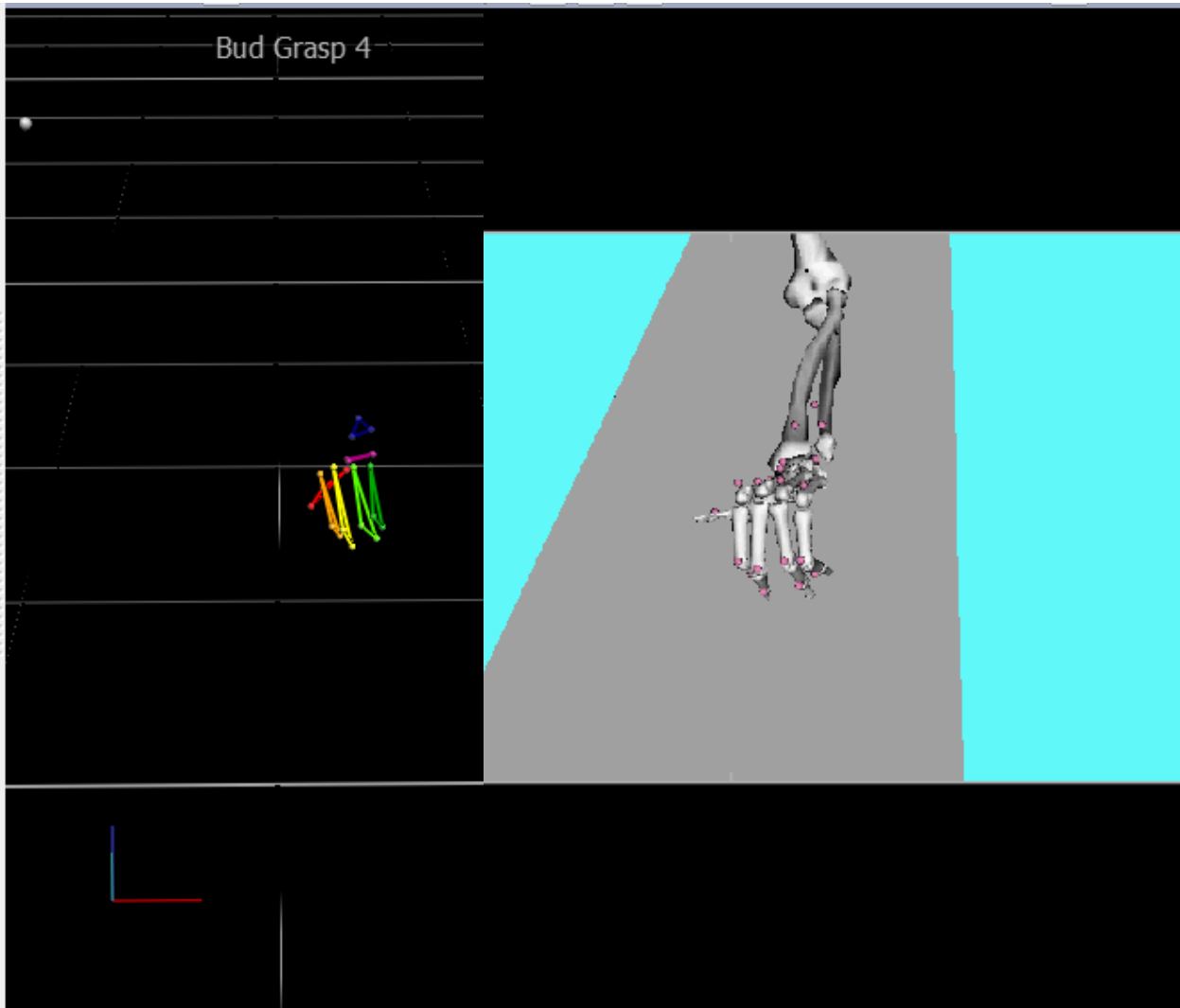


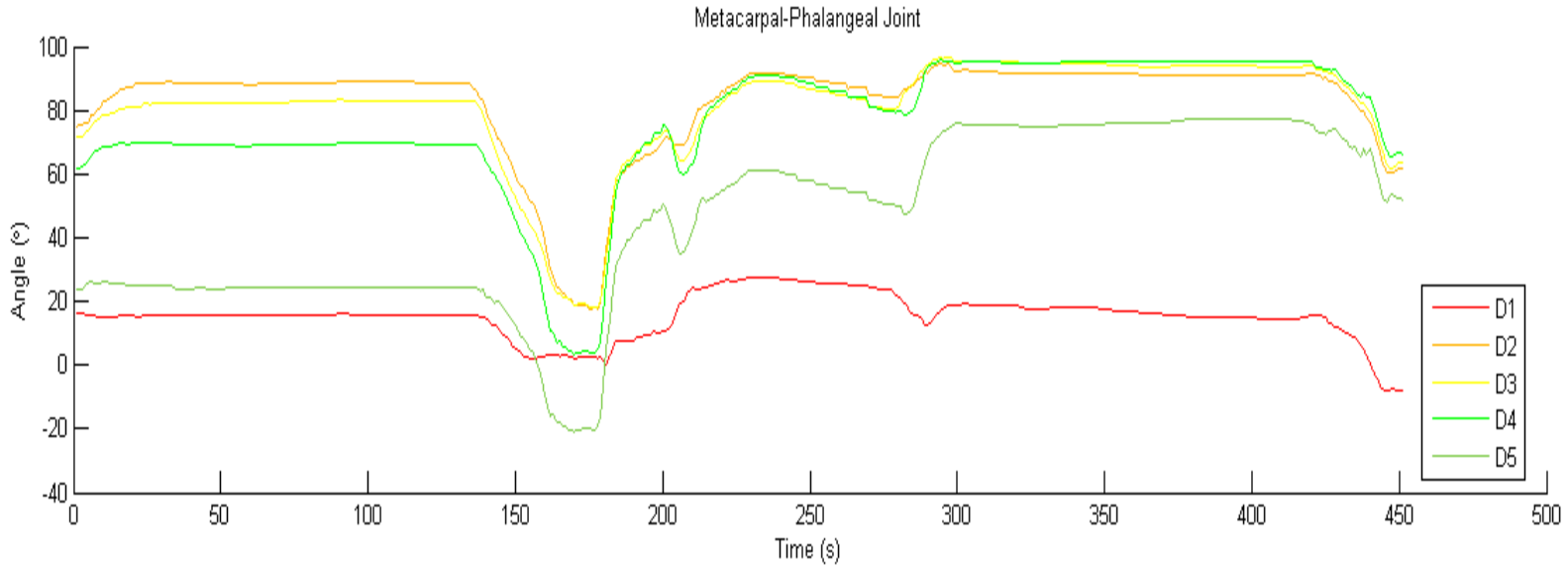
# Full body

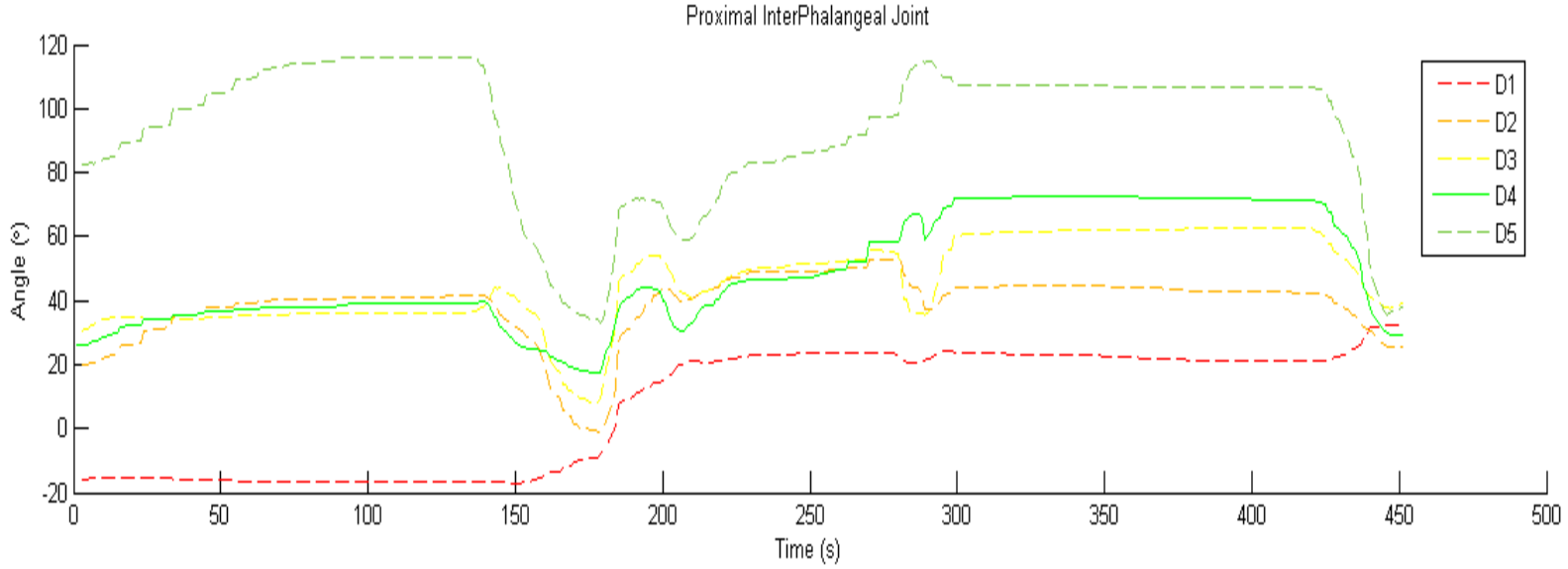


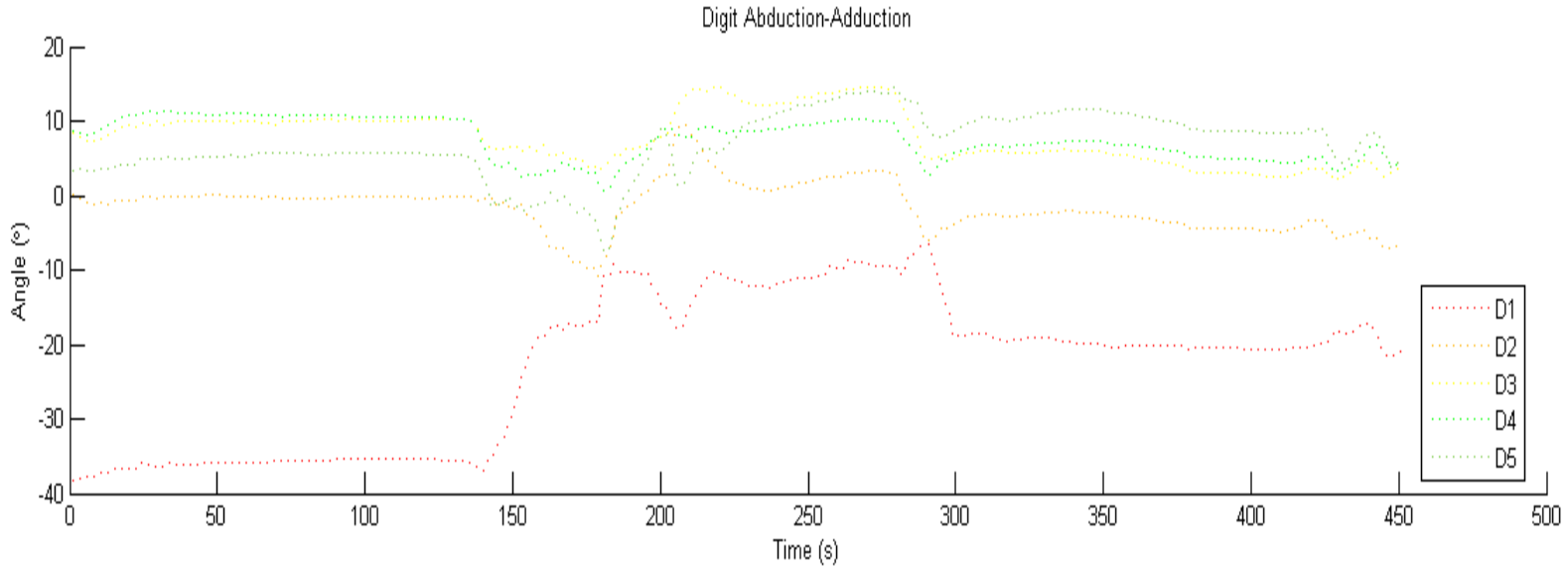
```
<Joint>
    <CustomJoint name="5prox-midph_l">
        <parent_body> 5proxph_l </parent_body>
        <location_in_parent>      -0.00410252      -0.02763735      0.00223739 </location_in_parent>
        <orientation_in_parent>      0.00000000      0.55000000      0.00000000 </orientation_in_parent>
        <location>      0.00000000      0.00000000      0.00000000 </location>
        <orientation>      0.00000000      0.00000000      0.00000000 </orientation>
        <!--Generalized coordinates parameterizing this joint.-->
```

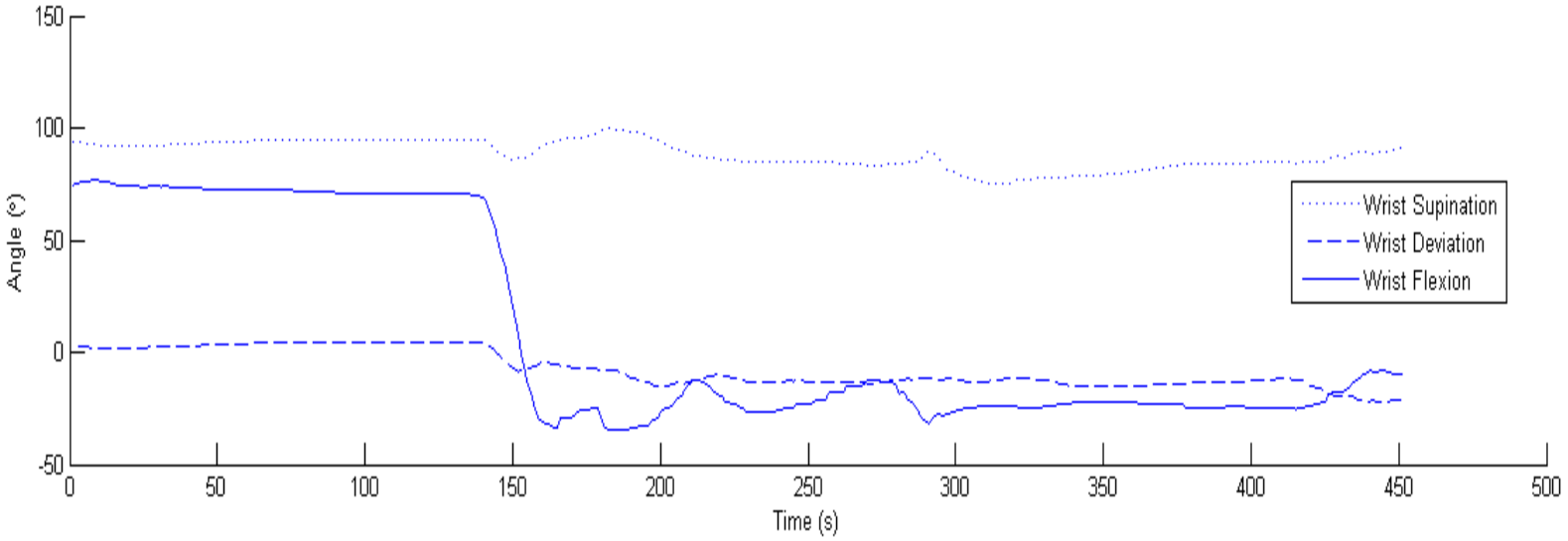
# Play Videos




Metacarpal-Phalangeal Joint
Angle (°)
Time (s)
D1
D2
D3
D4
D5


Proximal InterPhalangeal Joint
Angle (°)
Time (s)
D1
D2
D3
D4
D5


Digit Abduction-Adduction
Angle (°)
Time (s)
D1
D2
D3
D4
D5


Angle (°)
Time (s)
Wrist Supination
Wrist Deviation
Wrist Flexion

# Batch Processing

- Record over 350 trials in 1.5 hours each morning (even this week)
- Previous setup for batch processing would take hours instead of days

# Ongoing Issues – C3D Extraction Toolbox: Manual event timings

- C3D extraction toolbox - We can get the number of events defined on left/right and one of the three flags labeled in Nexus, but it seems that we can't get the timings of each events correctly. This issue is not exactly related to Opensim, but I am hoping that there would be some Vicon users that are more familiar to the toolbox than I am...

  Specifically - Most of the entries in C3D files can be extracted correctly after modifying some core files in the toolbox, but for

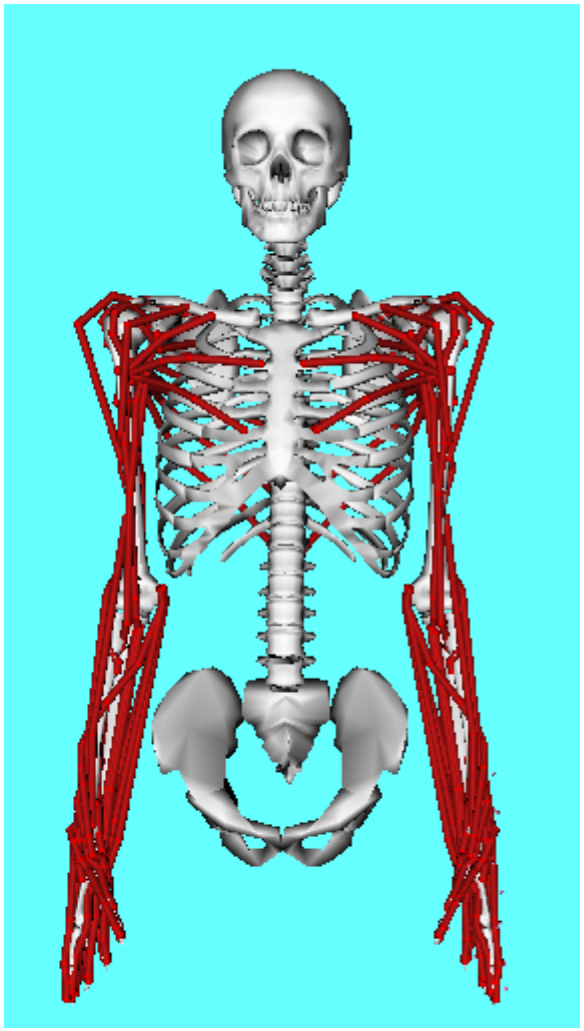
  EVENT_CONTEXT
  and
  EVENT

  there appear to be some discrepancy in terms of the times for events (EVENT.TIMES) and the number of entries for EVENT.TIMES is doubled to the number of the event and it is not clear to me how those times are organized, and in almost all the labeled C3D files we have, we don't get consistent time entries between the numbers seen in MlsViewer or getEvent function and the numbers directly extracted from C3D files using File I/O in Nexus (parcitularly using Advanced Ascii option).

# Future Directions

- Augment markerset to allow for shoulder and elbow movement
- Measure accurate rotation of D3-D5
- Add muscles and alter attachment points
  - Simulate muscle activations
  - Record EMG
- Bimanual Coordination

# End goal



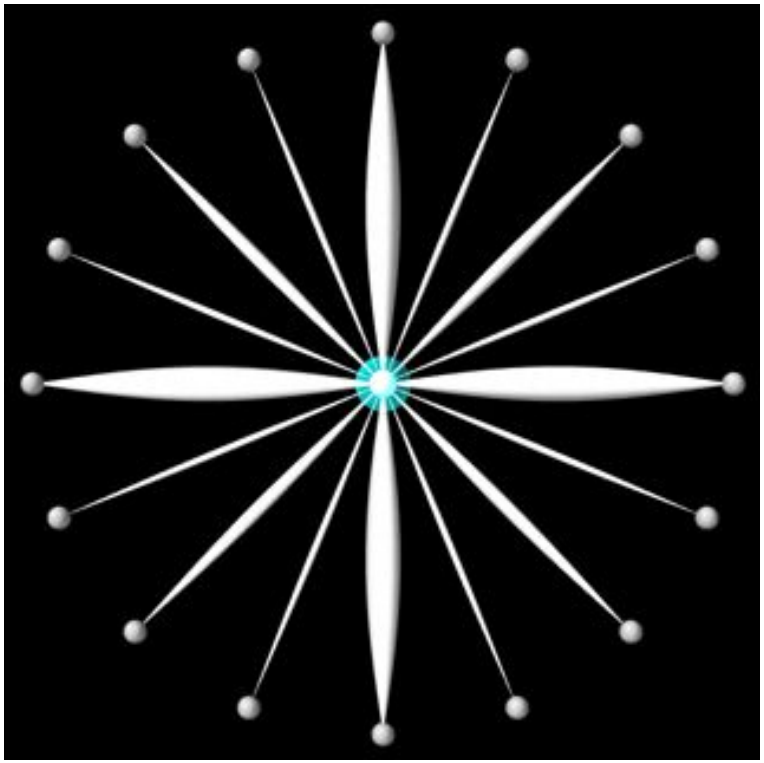
# Ian Stavness's Progress

## OpenSim Workshop August 2011

# Primary Goal to be Accomplished

**Can we modulate arm stiffness in a forward-dynamics simulation with muscle co-activation?**

e.g. 2-DOF particle model in ArtiSynth:

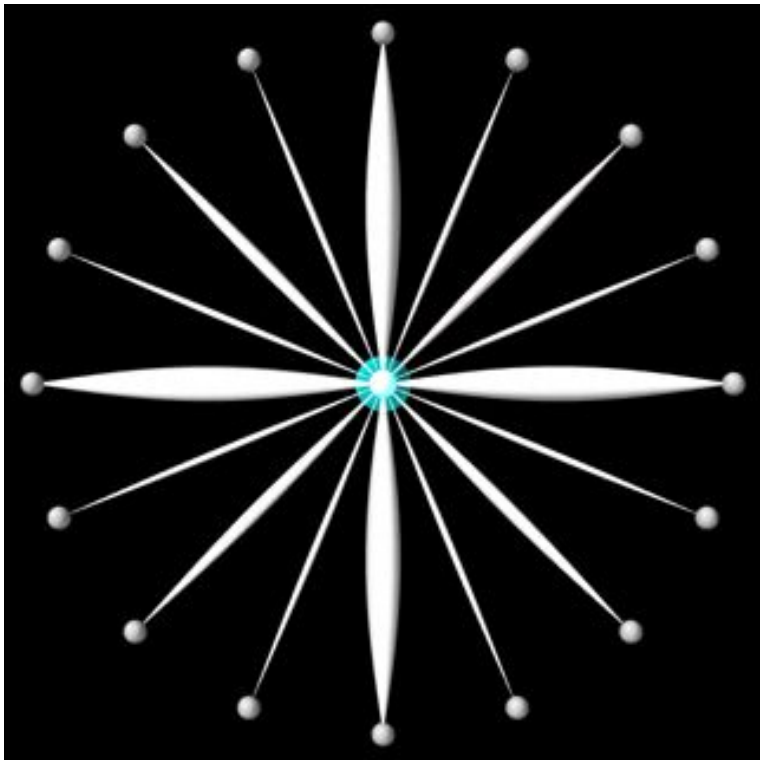


**Kinematic Target (cyan sphere)**

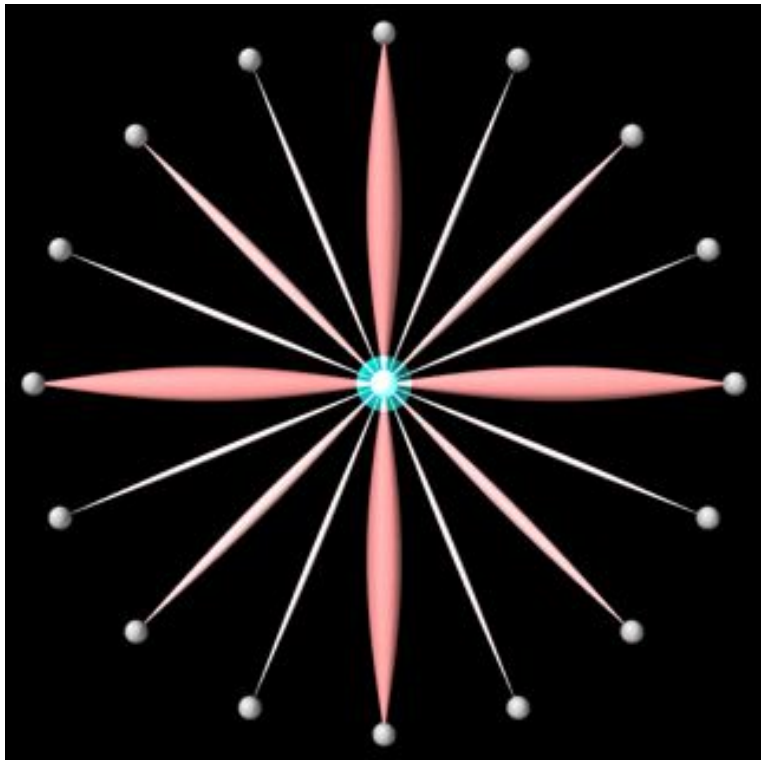
# Primary Goal to be Accomplished

**Can we modulate arm stiffness in a forward-dynamics simulation with muscle co-activation?**

e.g. 2-DOF particle model in ArtiSynth:



**Low Stiffness**

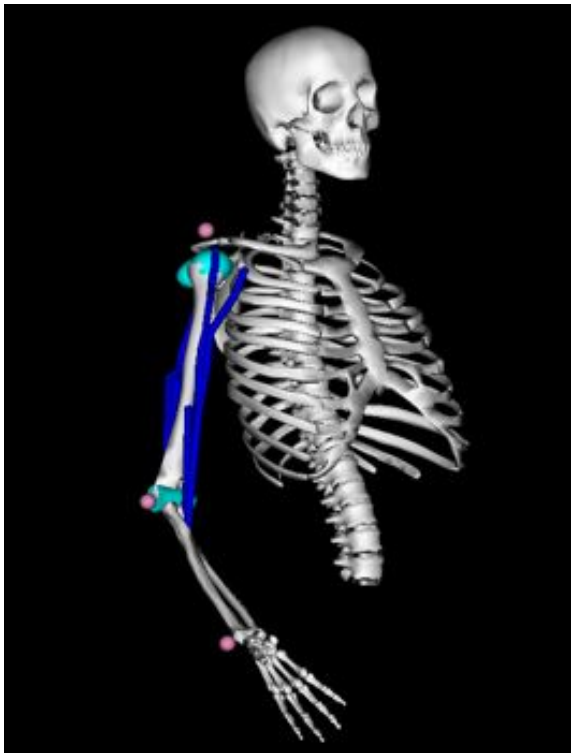


**High Stiffness**

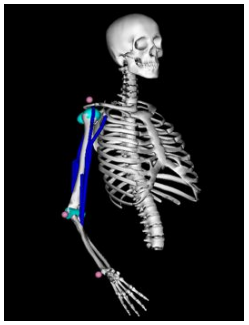
# Primary Goal to be Accomplished

**Can we modulate arm stiffness in a forward-dynamics simulation with muscle co-activation?**

Can we do the same with the Arm26 model?

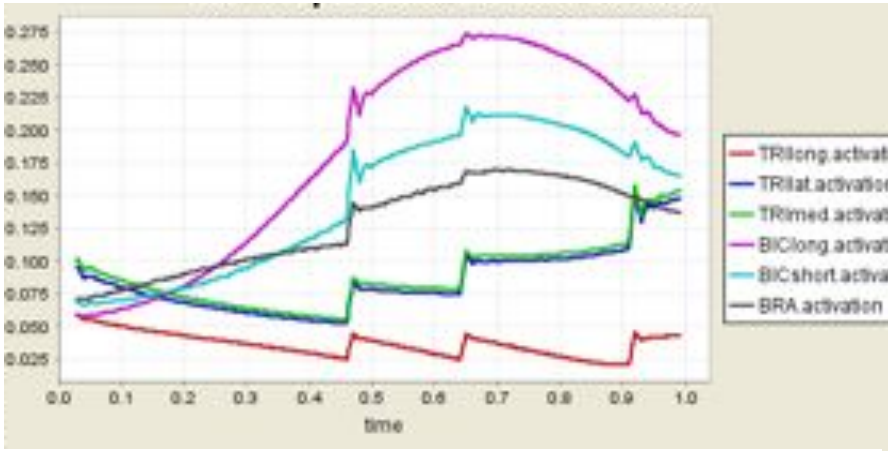


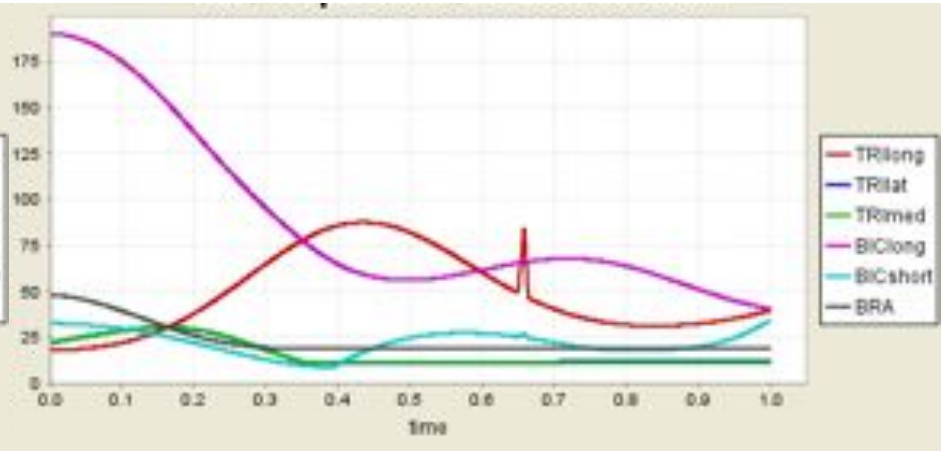
# Building Blocks in OpenSim



1. **Created CMC stimulation of arm movement, using GUI**

- **Next steps:** CMC parameters? Investigate RigidTendonMuscle further…




**Thelen2003Muscle:**

- good tracking
- discontinuities in muscle forces

**RigidTendonMuscle:**

- smooth muscle forces
- poor tracking

# Building Blocks in OpenSim

**2. Estimated arm stiffness, using API**

- Full stiffness matrix not used in explicit time integration
- Given a pose, $q$ compute generalized forces $\tau$

```
system = model.getMultibodySystem();
rigidBodyForces = system.getRigidBodyForces(state, Stage::Dynamics);
system.getMatterSubsystem().calcInternalGradientFromSpatial(
                            state, rigidBodyForces , generalizedForces);
```

- Implemented numerical stiffness estimation:

  $\Delta\tau = K\,\Delta q$

  $K \approx (\Delta q^T\,\Delta q)^{-1}\Delta q^T\,\Delta\tau$ – using `SimTK::FactorSVD`

- Created Arm26 model with **SpringGeneralizedForce** to test
- **Next step:** `SimTK::Differentiator`

# Future Plans

**1. FEM muscle models**

- Use OpenSim outputs to drive more complex muscle models

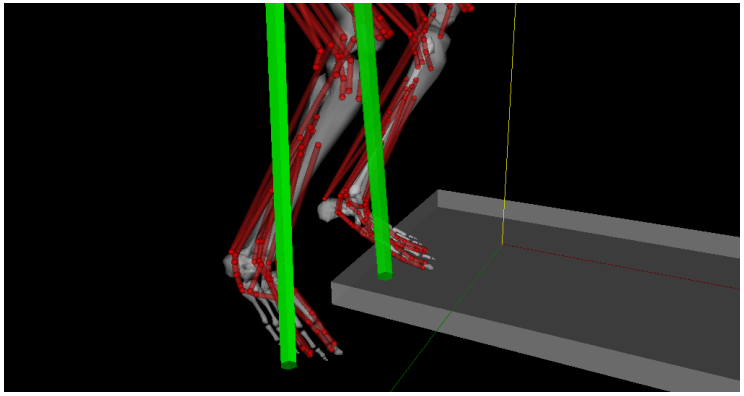
**2. Investigate connection between OpenSim and other open simulators:**

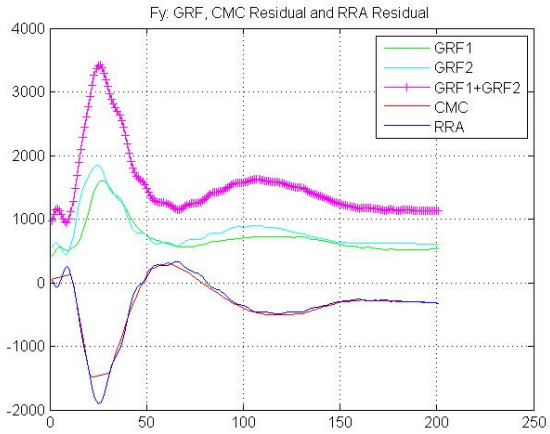
- ArtiSynth, FEBio, PhysBam, SOFA, …
- UBC JawHyoid model in OpenSim
- Arm26 model in ArtiSynth

**Di-An Hong**

**OpenSim Workshop August 2011**

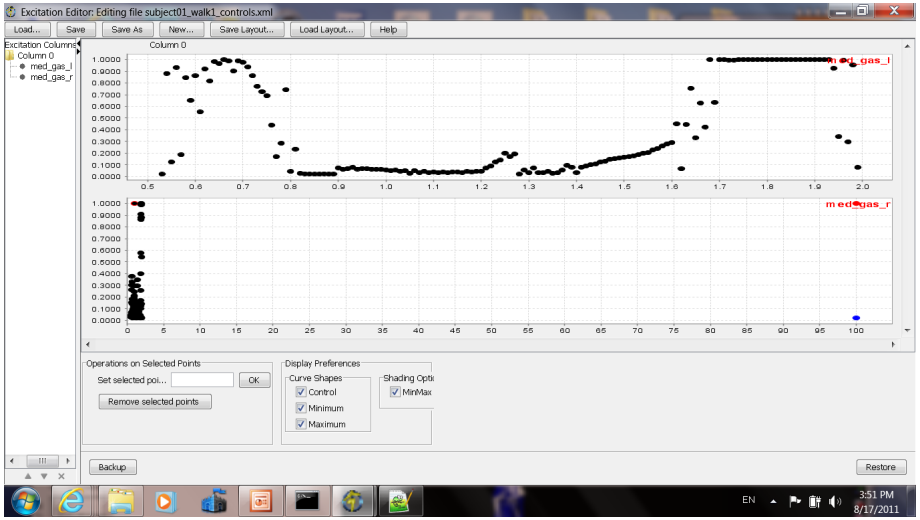
1. **Area of interest: Lower extremity injuries**
2. **Topics covered:**
   - How to alter the RRA and CMC control parameters that results in smaller residual forces/torques
   - How to integrate EMG as a control model for muscle force estimation
3. **V3D software problem**





# 4. Based on EMG data to constrain actuators:

ControlLinear name="med_gas_r.excitation">
<min_nodes>
<ControlLinearNode> <t> 1 </t> <value> 0.02 </value> </ControlLinearNode>
<ControlLinearNode> <t> 1.25 </t> <value> 0.02 </value> </ControlLinearNode>
<ControlLinearNode> <t> 100 </t> <value> 0.02 </value> </ControlLinearNode>
</min_nodes>
<max_nodes>
<ControlLinearNode> <t> 1 </t> <value> 1.0 </value> </ControlLinearNode>
<ControlLinearNode> <t> 1.25 </t> <value> 0.021 </value> </ControlLinearNode>
<ControlLinearNode> <t> 100 </t> <value> 1.0 </value> </ControlLinearNode>
</max_nodes>



## 5. Plan

- Re-do RRA and CMC with altering control parameters to obtain smaller residual forces/torques
- Integrate EMG for muscle forces estimation

THE UNIVERSITY OF WESTERN AUSTRALIA

*Achieving International Excellence*

# Cyril J. Donnelly's Information & Goals

## OpenSim Workshop August 2011

# Cyril J. Donnelly

## 1. School of Sport Science Exercise and Health

- Cyril J. Donnelly, MSc., Lecturer, University of Western Australia

## 2. Area(s) of interest:

- Creating subject specific joint axes
- Use inverse kinematics and subject specific joint axes to increase the accuracy of joint angle outputs

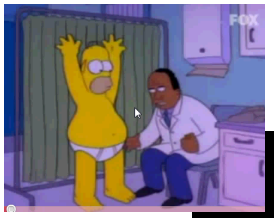
## 3. Topics you want to see covered:

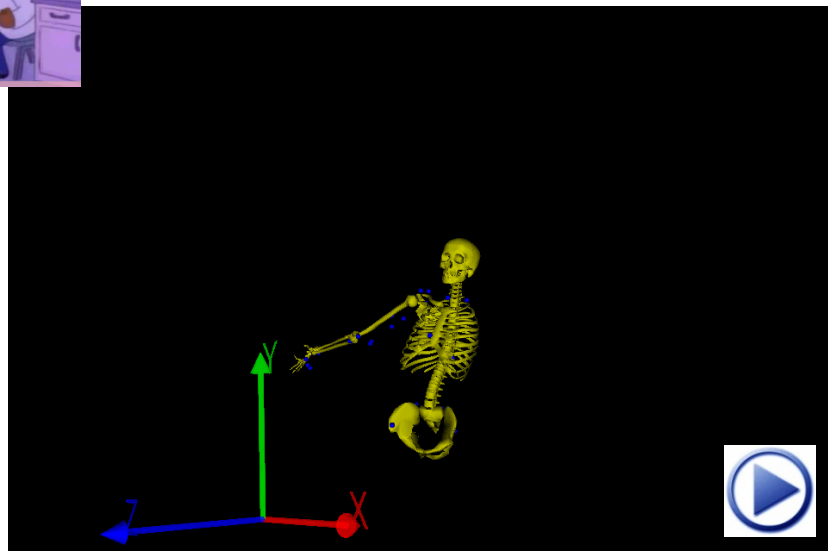
- Obtain steps for adding/modifying joints and joint axes
- Walk away with a complete and thorough understanding of how joint axes are defined during scaling and determine the simplest and most accurate method for implementing/defining subject specific joint axes.

# Cyril J. Donnelly's Primary Goal

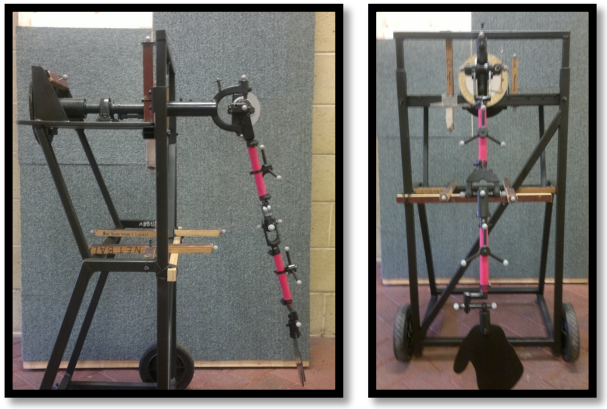
**4. Increase the accuracy of elbow joint angle outputs during cricket bowling using by inverse kinematics and subject specific joint axes.**

- Law 24.3 ~ Illegal bowling action: elbow extension from horizontal arm position to ball release > 15º (ICC Operations Manual, 2006).





**Mechanical linkage arm**

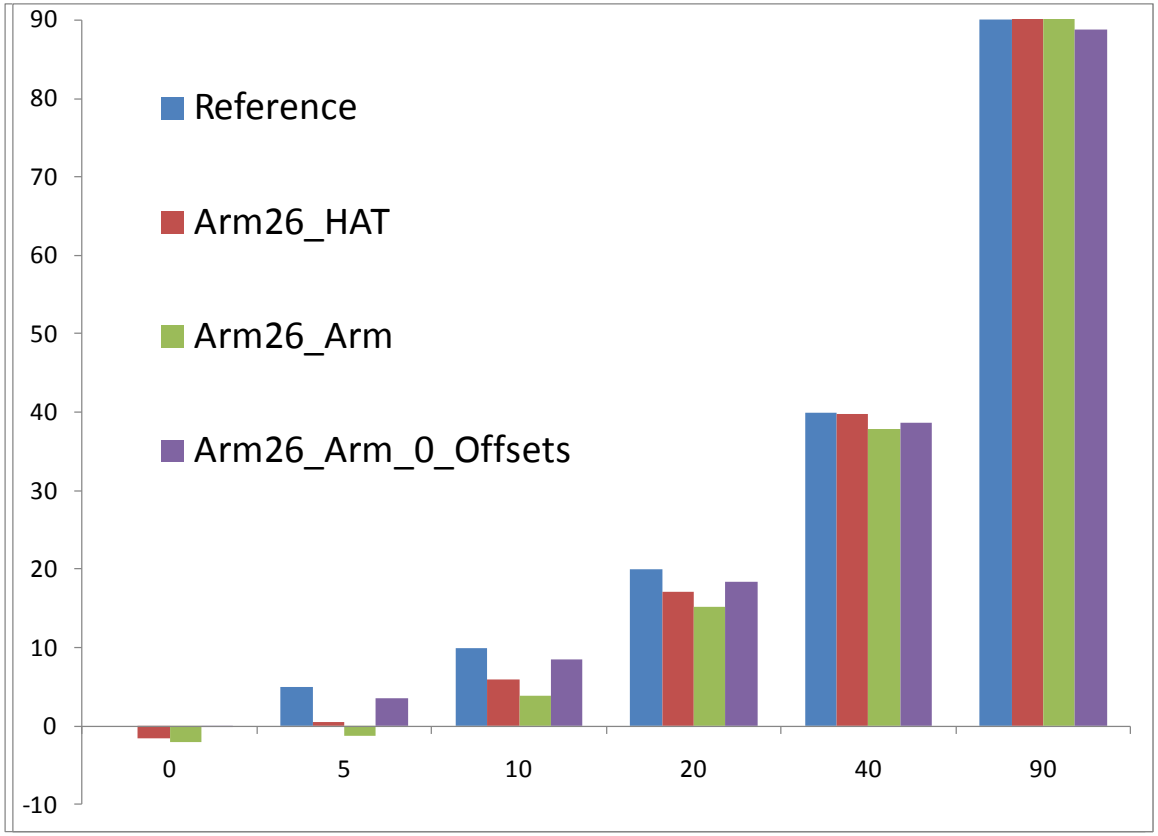


Frontal Plane Sagittal Plane

# Cyril J. Donnelly's Progress

## 5. Reliability of IK using a 1 DoF elbow model

- Mean error: 1.2 ±0.5 degrees... still a bit of work to do.



# Cyril J. Donnelly's Light Bulb Moment

```
<BodySet name="">
    <objects>
        <Body name="ground">
        <Body name="l_upper_arm">
        <Body name="l_ulna_radius_hand">
            <mass>        1.53431500 </mass>
            <mass_center>        0.00000000       -0.21621488        0.00000000 </mass_center>
            <inertia_xx>        0.01928100 </inertia_xx>
            <inertia_yy>        0.00157100 </inertia_yy>
            <inertia_zz>        0.02006200 </inertia_zz>
            <inertia_xy>        0.00000000 </inertia_xy>
            <inertia_xz>        0.00000000 </inertia_xz>
            <inertia_yz>        0.00000000 </inertia_yz>
            <!--Joint that connects this body with the parent body.-->
            <Joint>
                <CustomJoint name="l_elbow">
                    <parent_body> l_upper_arm </parent_body>
                    <location_in_parent>        0.00000000       -0.37973175        0.00000000 </location_in_parent>
                    <orientation_in_parent>        0.00000000        0.00000000        0.00000000 </orientation_in_parent>
                    <location>        0.00000000        0.00000000        0.00000000 </location>
                    <orientation>        0.00000000        0.00000000        0.00000000 </orientation>
                    <!--Generalized coordinates parameterizing this joint.-->
                    <CoordinateSet name="">
                    <reverse> false </reverse>
                    <SpatialTransform name="">
```

## Cyril J. Donnelly's Future Goals

# 6. Reliability of IK using HAT model

-Change abduction angle of elbow

-Trial a hinge joint v custom joint

-Dynamic ROM tasks (low accel)

-Cricket bowling trial (high accel)

-OSIM (IK) v UWA model

# Team Sim-ian: Final Report

## OpenSim Workshop August 2011

# Project Overview

## 1. Team

- Brian Umberger
- Matt O'Neill
- Leng-Feng Lee
- Michelle LaBoda

## 2. Research Interests

- Mechanics and energetics of locomotion
- Evolution of bipedalism

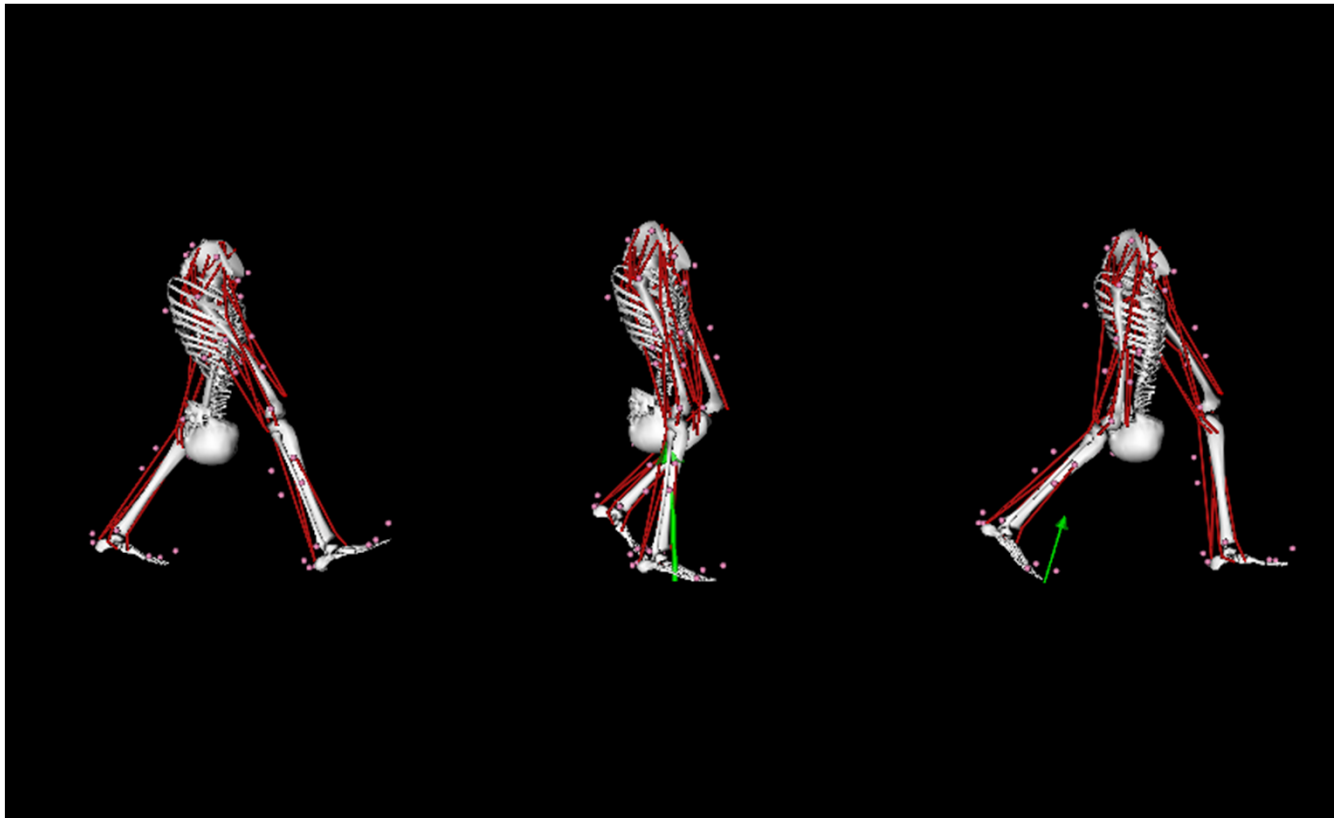
## 3. Project

- Modeling and simulation of chimpanzee and human walking

## 3. Workshop Goals

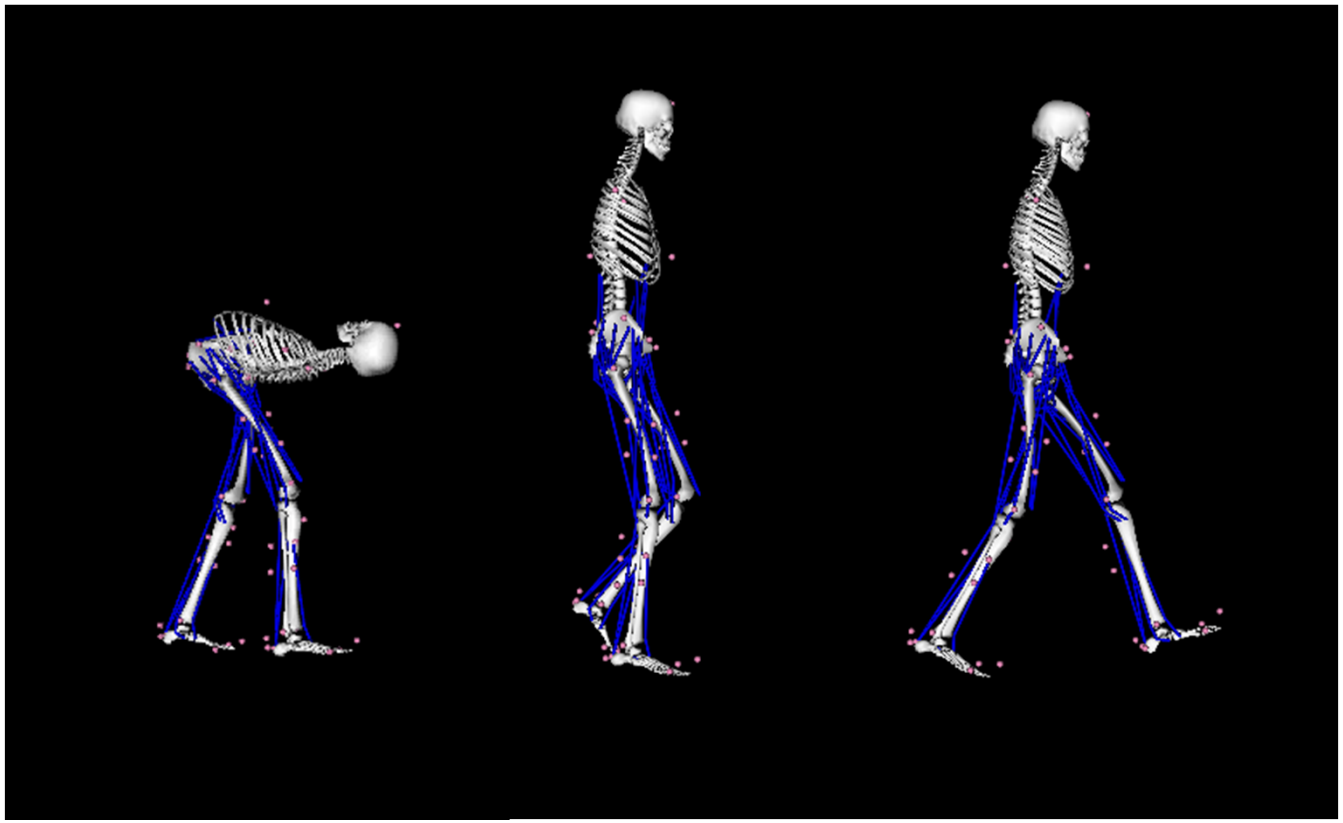
- Generate simulations with reduced marker data: Scale, Inv Kin, Inv Dyn
- Create a new OpenSim chimpanzee musculoskeletal model: Forward Dyn

# Goal 1: Pre-Workshop



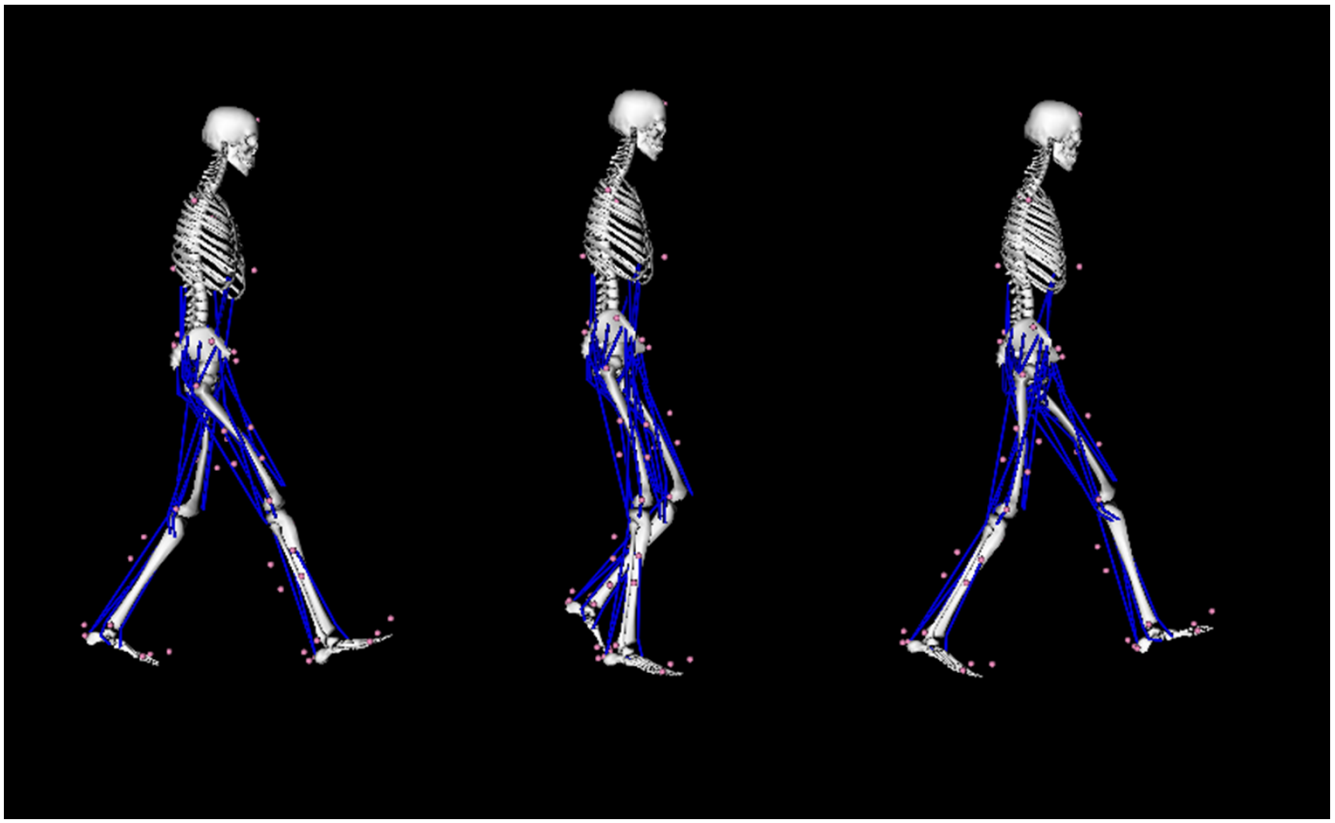
problems with marker definitions

# Goal 1: Early-Workshop



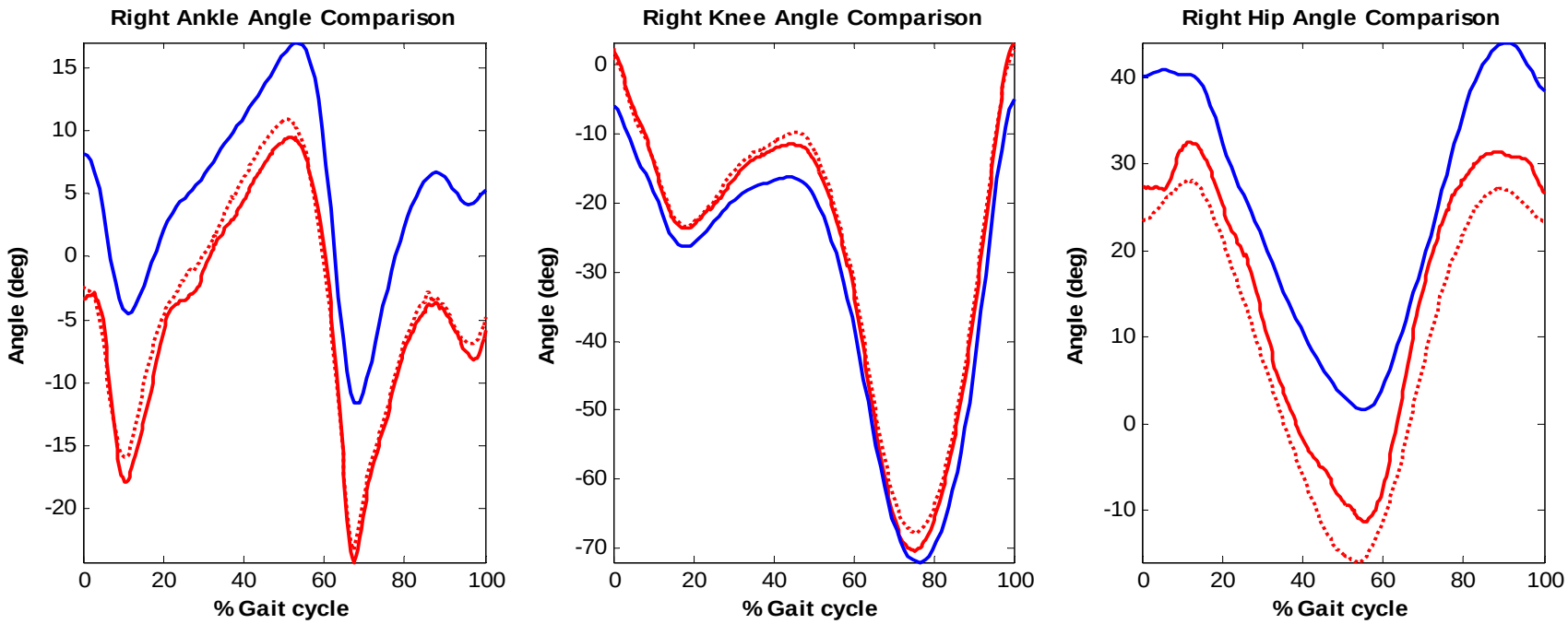
getting closer …

# Goal 1: Final Workshop Result



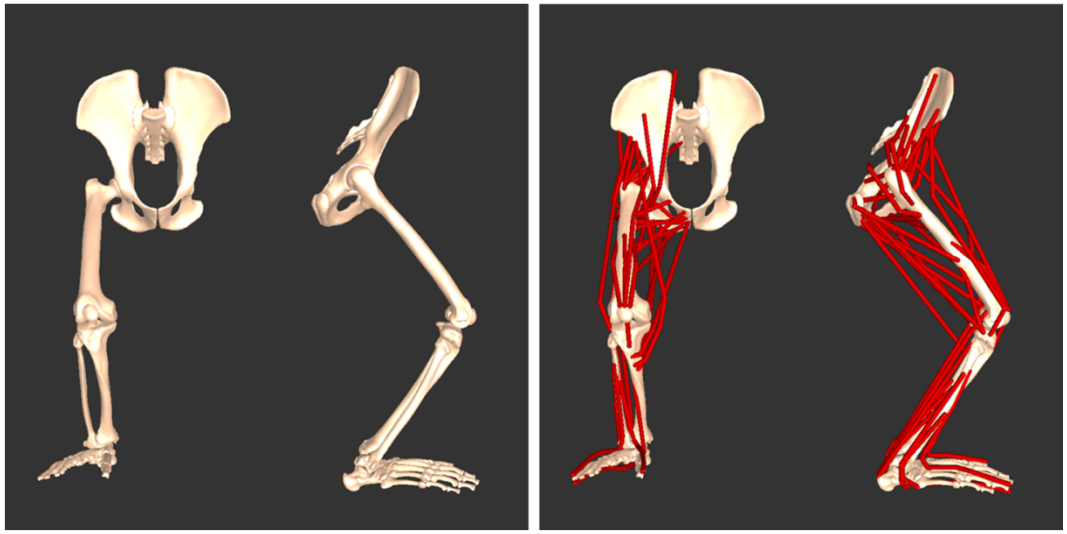
success: rms error ≈ 1.5 cm
max error ≈ 4.0 cm

# Goal 1: Joint Angles: OpenSim vs. Visual3D

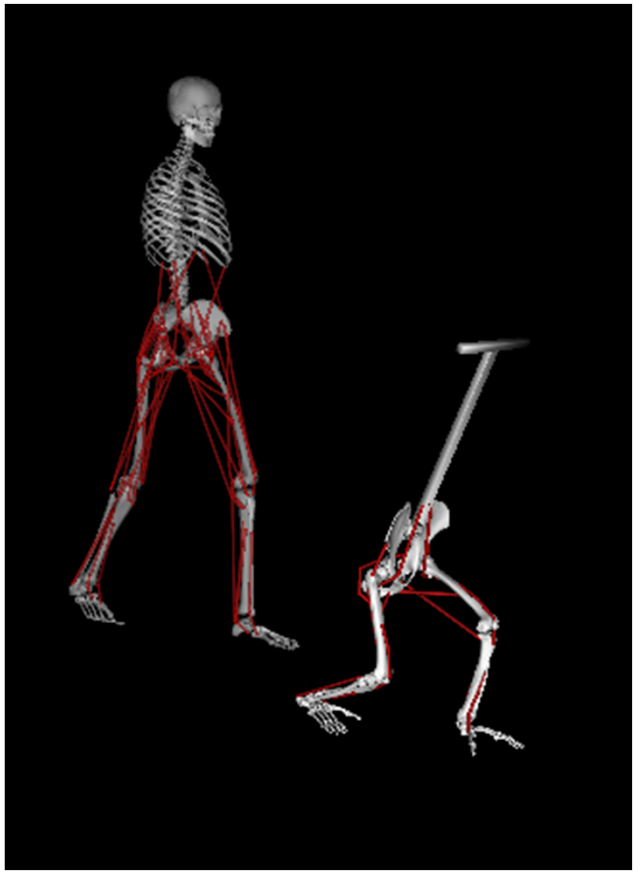



Good agreement in curve shapes; still need to work on scaling and weights for inverse kinematics

# Goal 2: Chimpanzee Model

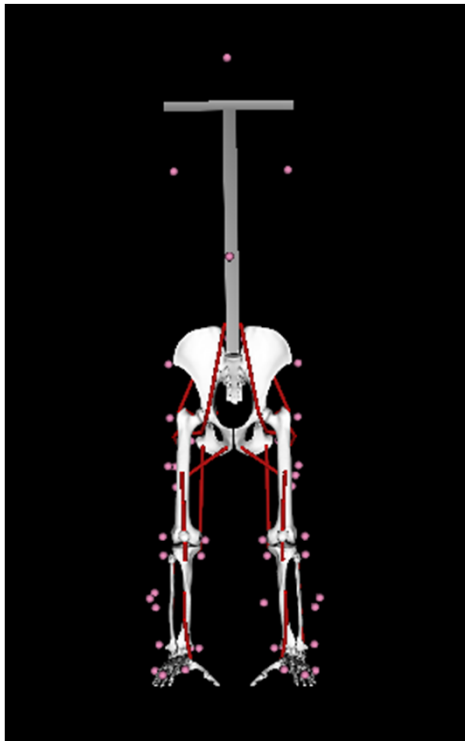


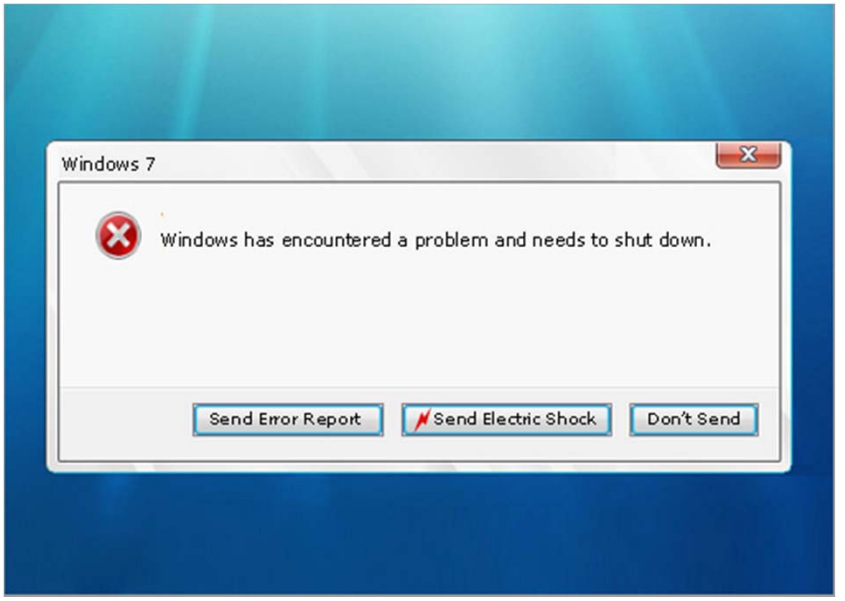
chimpanzee hindlimb model in SIMM



size relative to human model in OpenSim

# Goal 2: Pre-Workshop

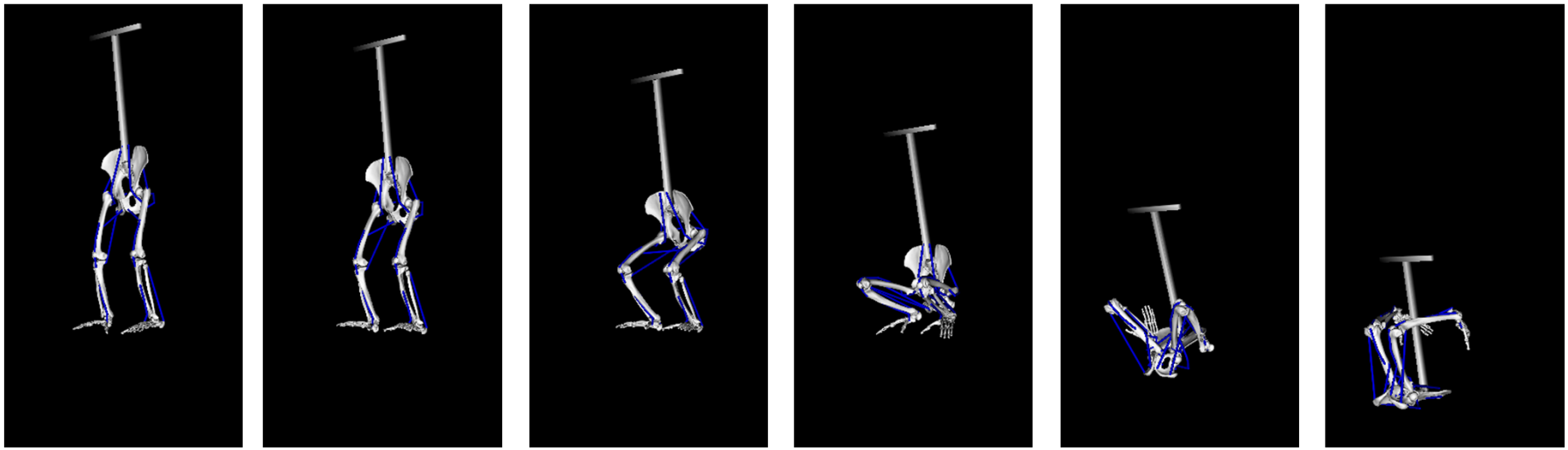





We could load the model, but if we tried to run a simulation it would crash

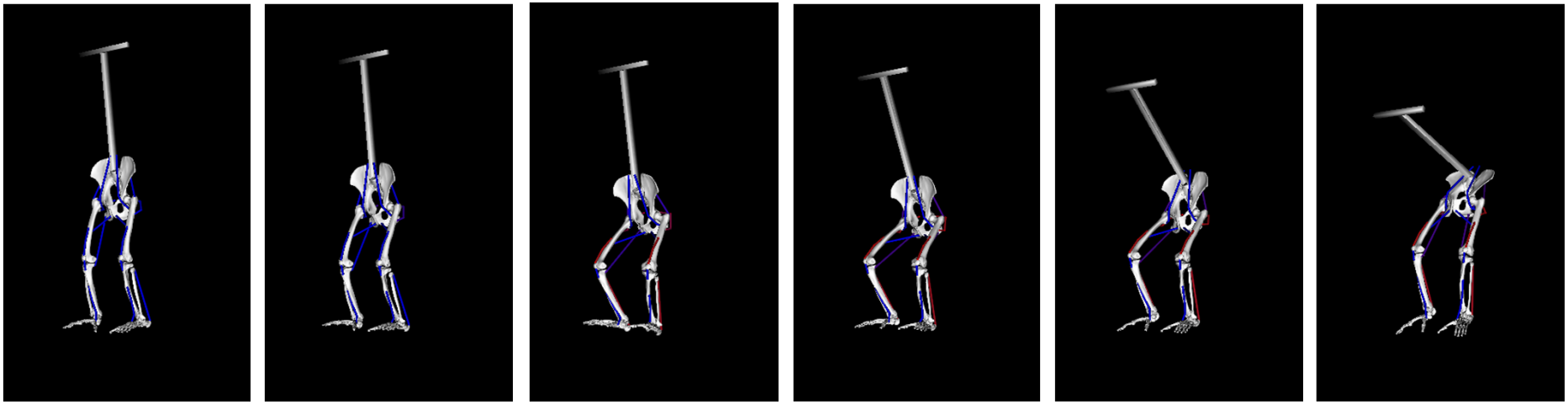
Error was traced to a massless patella

# Goal 2: Early-Workshop



Free-fall simulation with a point constraint under each foot (approximately at center of pressure)

# Goal 2: Final Workshop Result



By-hand muscle excitations that keep the model from falling over for 0.5 s

# Future Work

## 1. Goal 1

- Follow up on RRA & CMC analyses with our human data
- Work on accessing models from outside of GUI

## 2. Goal 2

- Implement full chimpanzee model in OpenSim
- Work on scaling, inv kin, and inv dyn with chimp model as our experimental data become available


## Acknowledgments

- OpenSim team!
- NSF: BCS-0935327 and BCS-0935321

Someday...