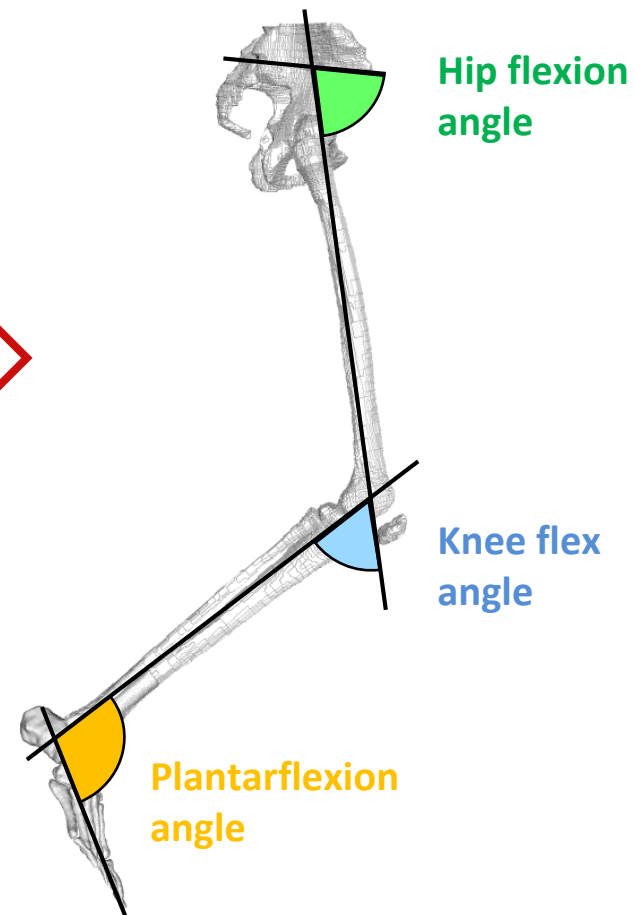
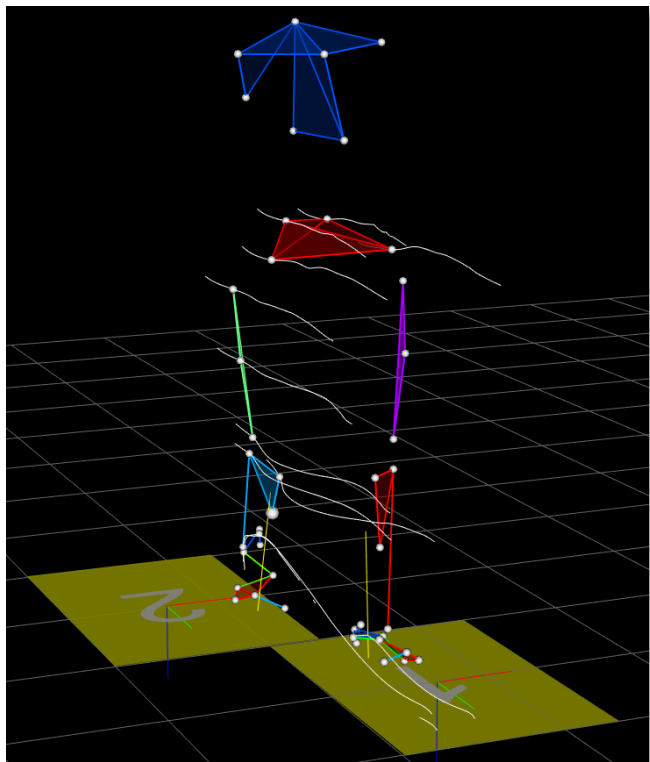


Inverse Kinematics

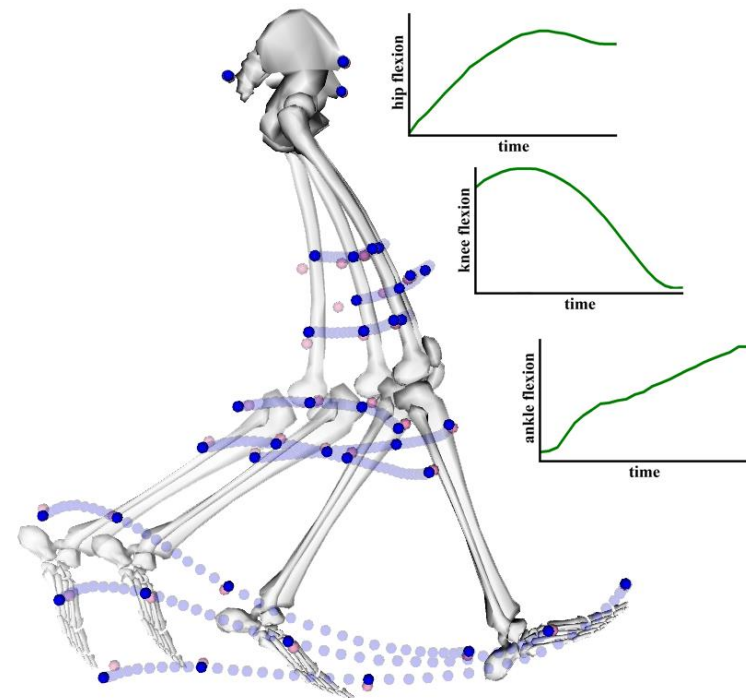
OpenSim Workshop

Kinematic analysis

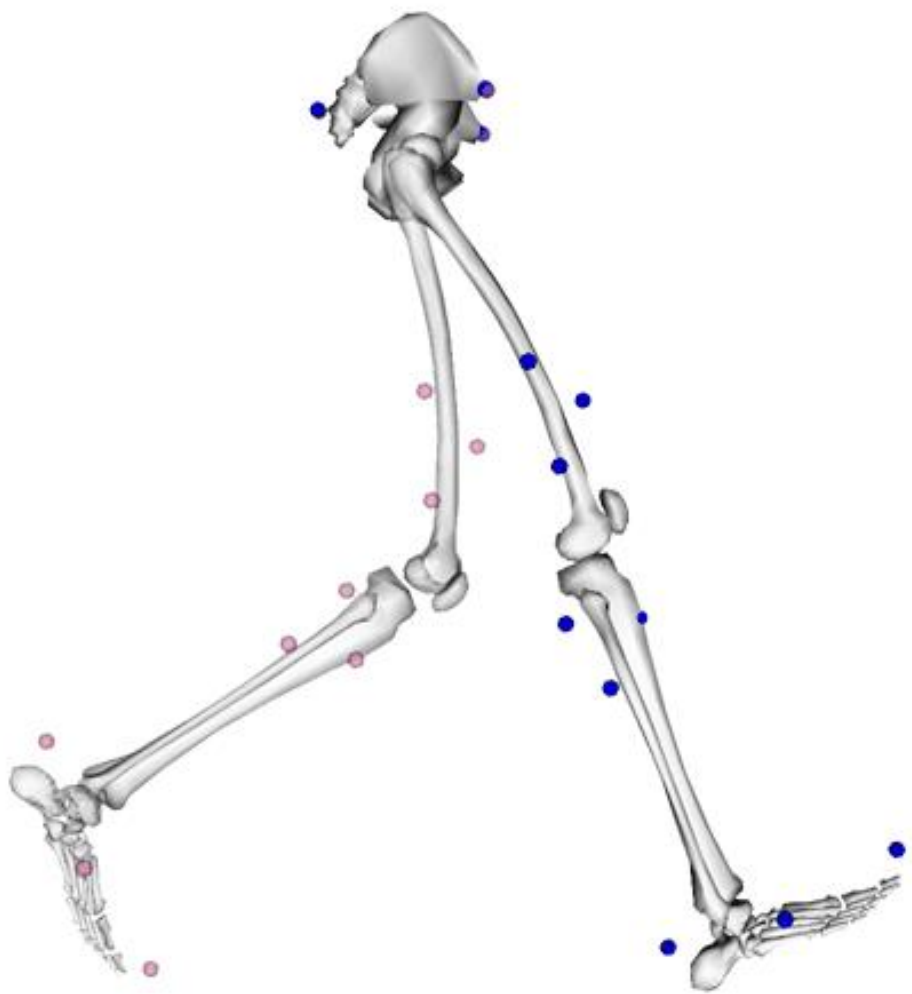


What does the inverse kinematics (IK) tool do?

- Finds the coordinates (joint angles) of a scaled model that best match measured kinematics.
- To do this, it solves a weighted least square minimization problem



Marker Error

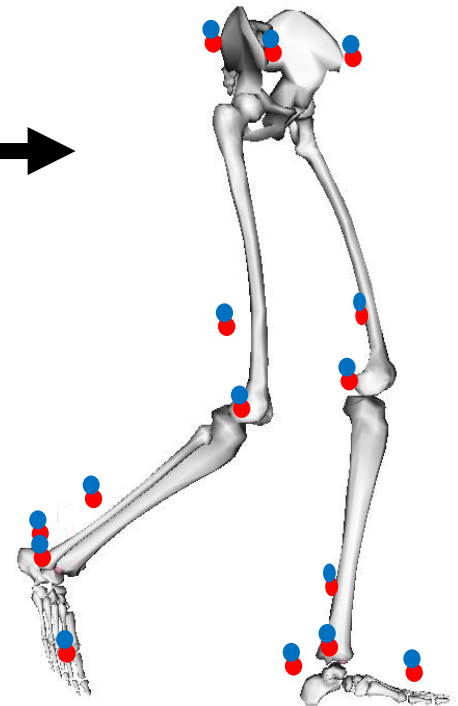
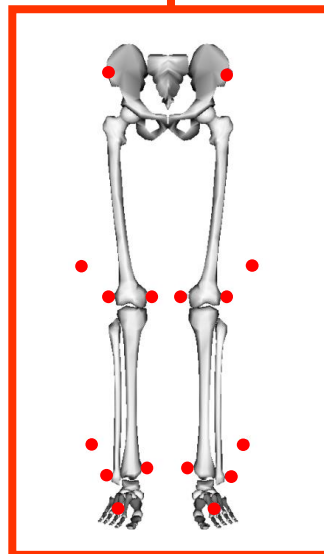
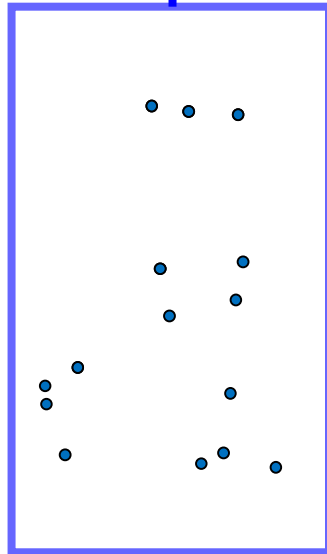


Marker Error

Inverse kinematics

- IK minimizes the sum of **weighted** marker tracking errors squared

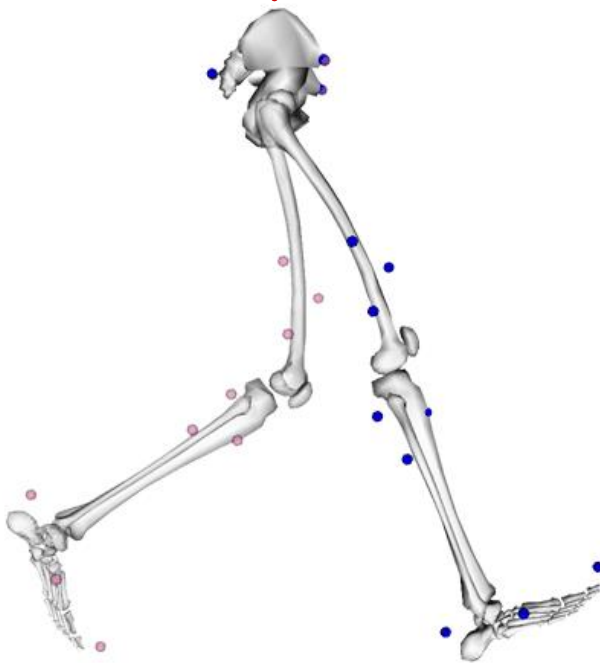
$$\min_{\vec{q}} \sum_{i=1}^{\#Markers} w_i \|\vec{x}_i^{exp} - \vec{x}_i(\vec{q})\|^2$$



Lu and O'Connor JBiomech 1999

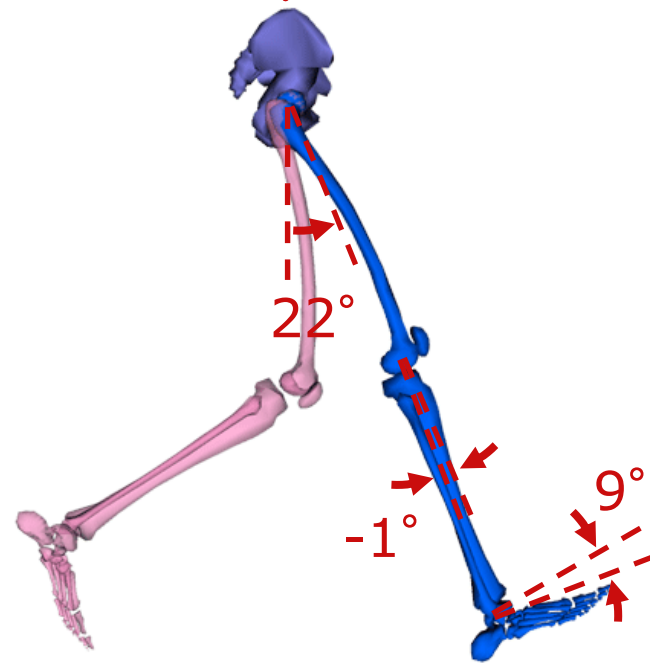
Extended Weighted Least Squares Minimization

$$\min_q \left[\sum_{m=1}^{\# \text{ markers}} w_m \left\| \mathbf{x}_m^{\text{exp}} - \mathbf{x}_m(\mathbf{q}) \right\|^2 + \sum_{c=1}^{\# \text{ coordinates}} \omega_c \left(q_c^{\text{exp}} - q_c \right)^2 \right]$$



Marker Error

+

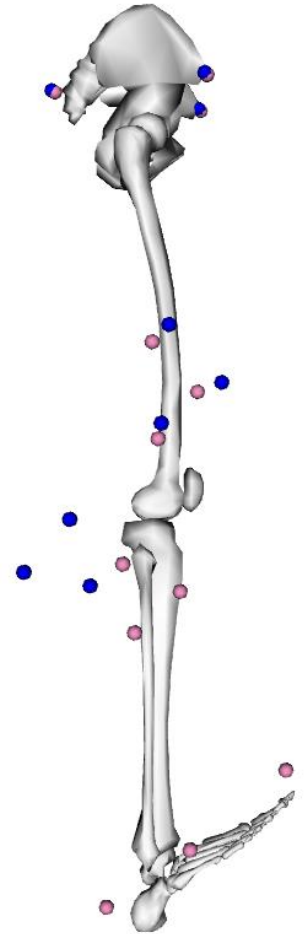


Coordinate Error

Exercise

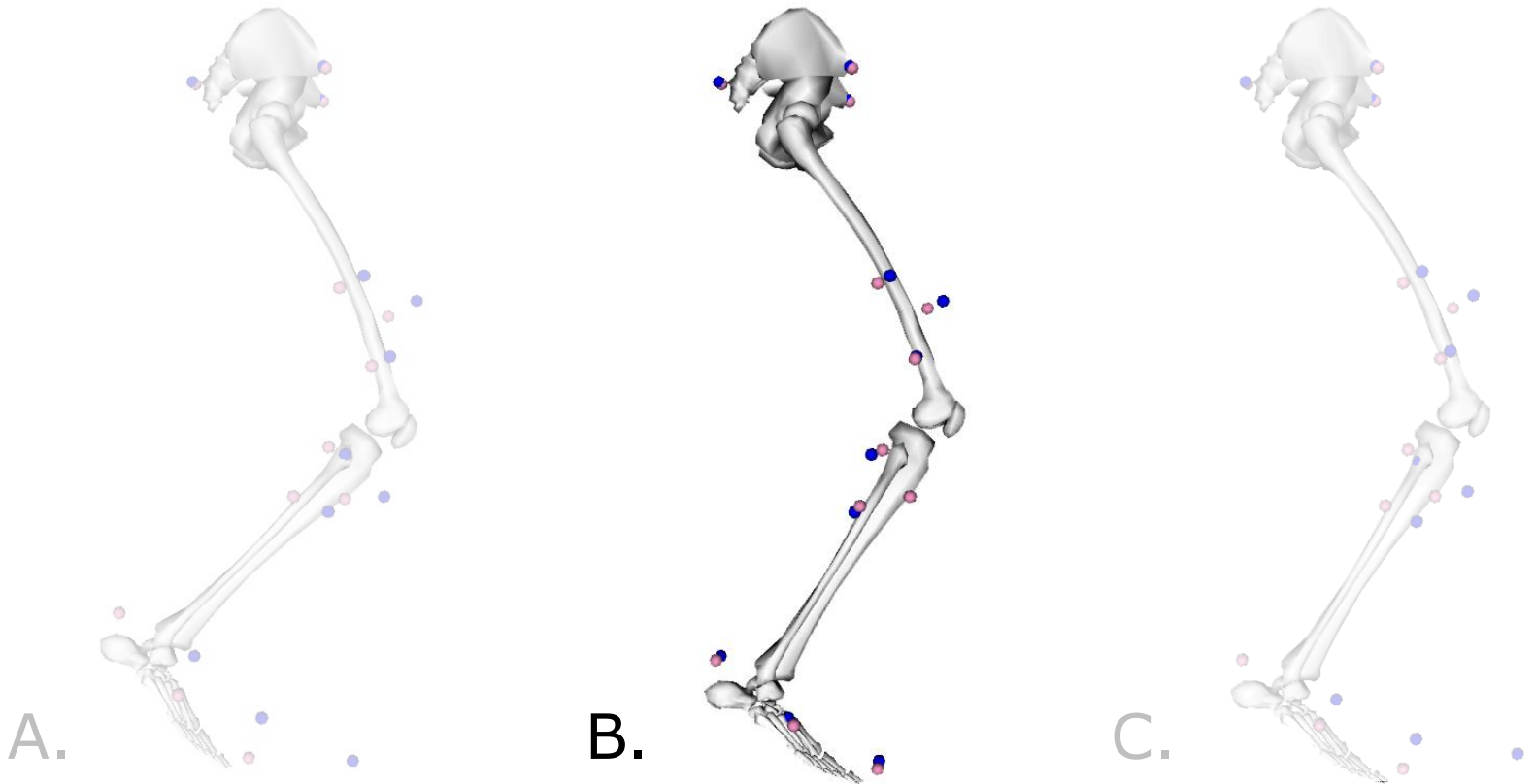
1. For the model shown on the right, which **coordinate(s)** need to be ***adjusted to*** create a model pose that ***“best matches”*** the **experimental markers** shown at the beginning of swing phase?

- A. Hip
- B. Knee
- C. Ankle
- D. Hip and ankle
- E. Knee and ankle



Exercise

2. For the **model poses** and experimental markers shown below, which combination of pose and markers has the ***minimum*** marker errors?

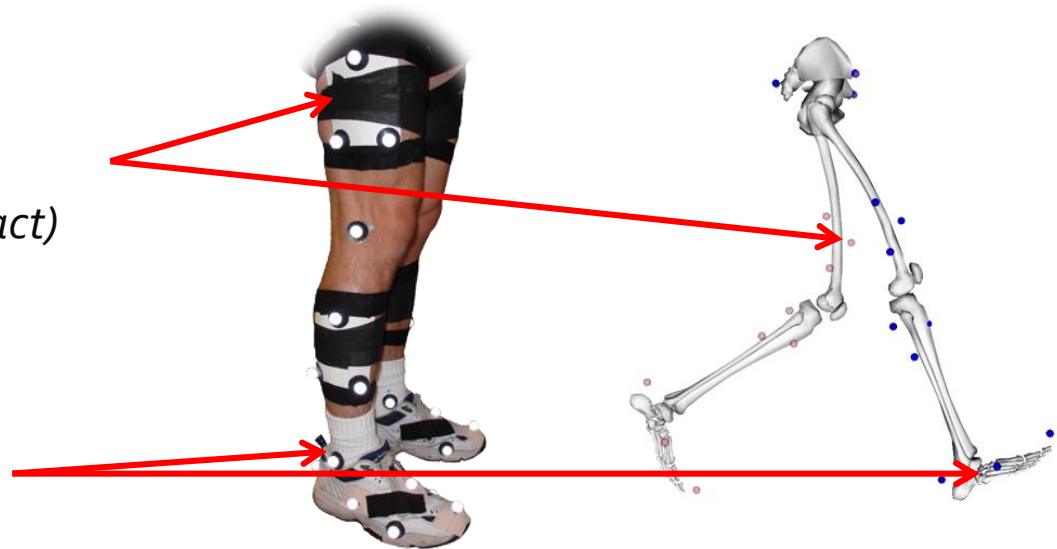


Inverse Kinematics in two steps

1. On subject: Collect **dynamic trial** (*.trc)
2. For IK Tool: Create **set-up file** for IK that specifies:
 - **trc** file containing **marker trajectories**
 - **weights** for marker tracking

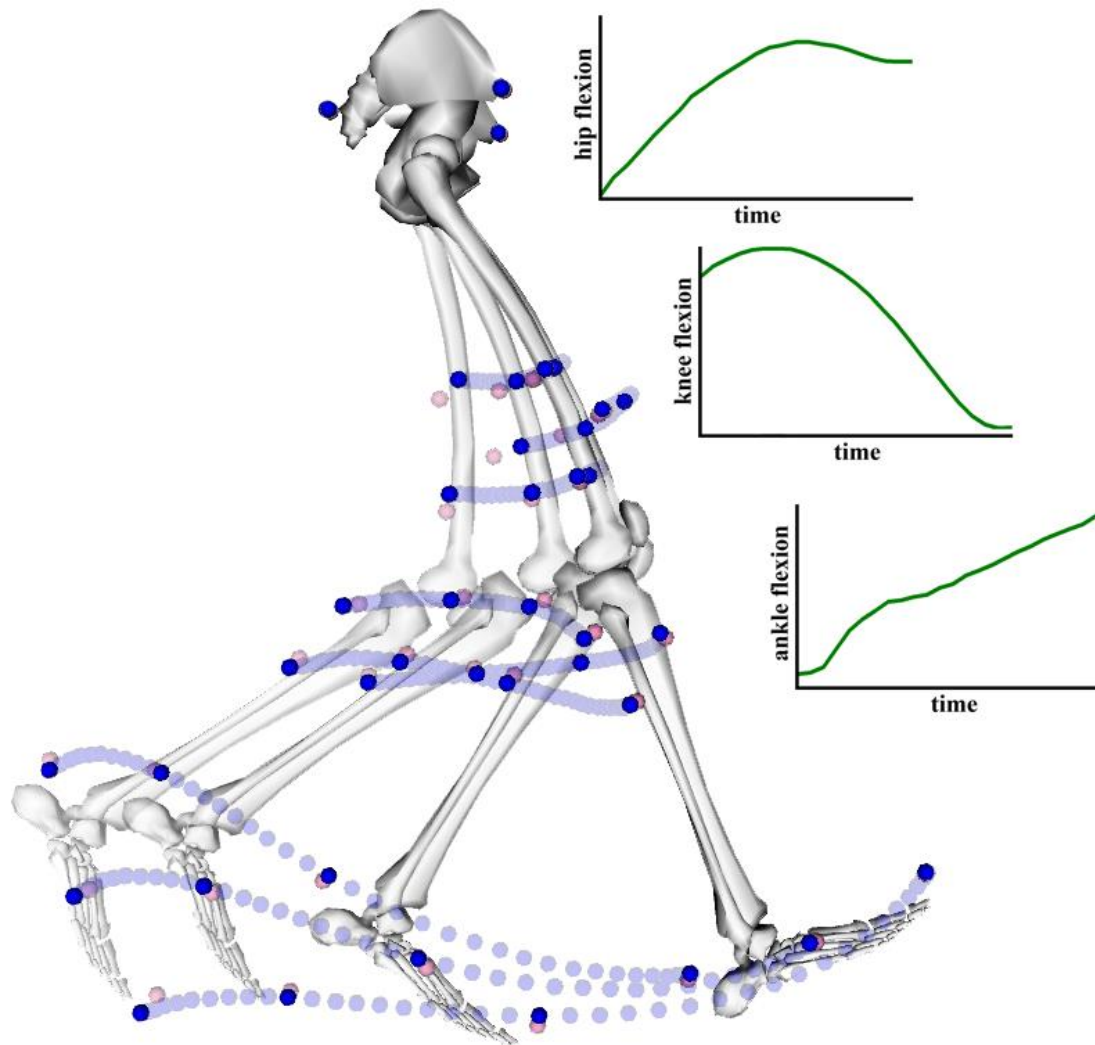
Lower weights to markers you have less confidence in (e.g. due to skin motion artifact)

Higher weights to important markers (e.g. ankle marker)



See the **OpenSim User's Guide** and **Video Tutorials** for more information

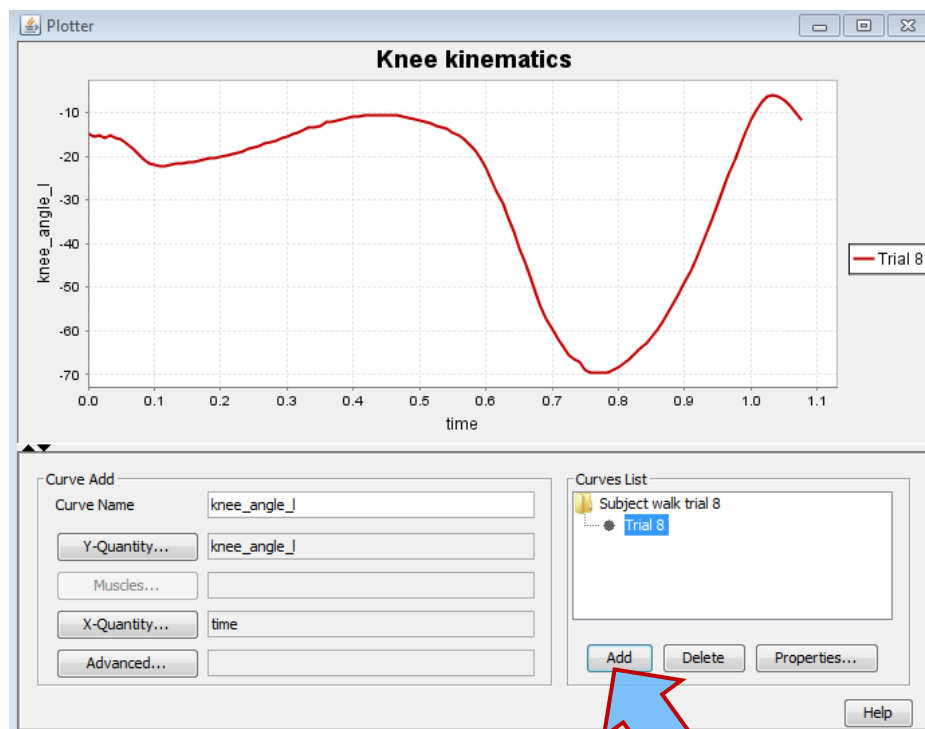
Using Opensim's IK Tool (Demo)



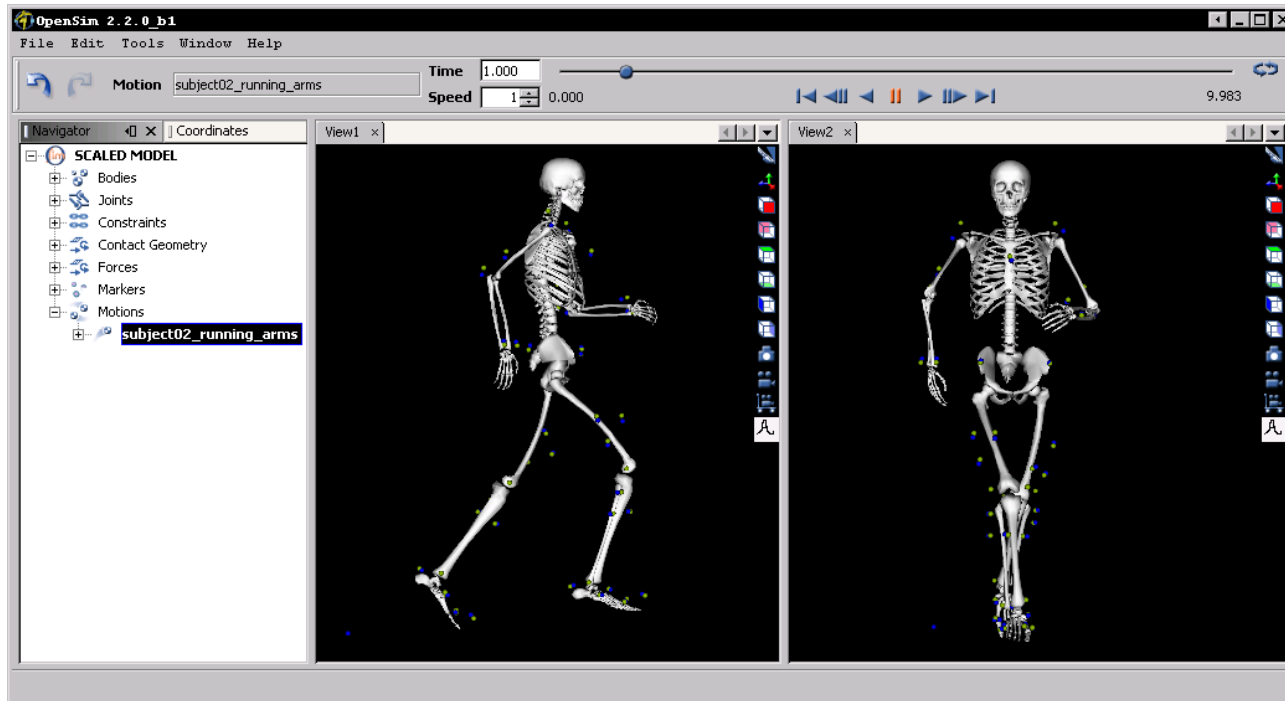
Plotting the IK results

Let's plot *knee angle vs time*

- Click **Y-Quantity**
Select **Coordinates**, then **knee_angle_I**
- Click **X-Quantity**
Select **time**
- In **Curves List**, edit **Figure 1**
to name your curve
e.g., "Trial 8"
- Click **Add**



Tips and tricks



Marker weights are relative

Check max and RMS marker errors in messages window

Weight "motion" marker triads on body segments higher than anatomical markers

Max marker error should be < 2 cm with RMS error < 1 cm