MCEN 4228/5228
Modeling of Human Movement
(K): Knowledge Problem, (C): Challenge Problem, (EX): Extra Credit
HW05

Part I (K)

In the first part of this homework assignment, you will complete two tutorials for OpenSim, which is widely used computer software for creating and analyzing models of the musculoskeletal system. OpenSim incorporates all of the properties of the muscle that we have talked about in class, and ultimately makes your life easier because you don't have to use pen and paper to calculate and solve for things like moment arms, fiber lengths, forces, moments, etc. It also captures the effects of all of these complexities for you so you don't have to ignore tendons, nonlinear properties, etc.

Go to the "simtk" web site, create an account (it's free and fast), and download the OpenSim 4.0 software (available on PC and Mac). Here is the link: https://simtk.org/frs/?group_id=91

Problem 1
Complete Tutorial 1 (link below), and as you complete it, answer the questions that are listed below.
http://simtk-confluence.stanford.edu:8080/display/OpenSim/Tutorial+1+-+Intro+to+Musculoskeletal+Modeling

a) How many degrees of freedom does the model have? List the joints and the anatomical planes in which the movement occurs. Which motions have been simplified and how so?
b) Name three muscles in the model that are represented with multiple lines of action. Why do you think these muscles are represented in this way?
c) At what knee angles do the rectus femoris and vastus intermedius moment arms peak?
d) What differences do you observe between normal gait and crouch gait?

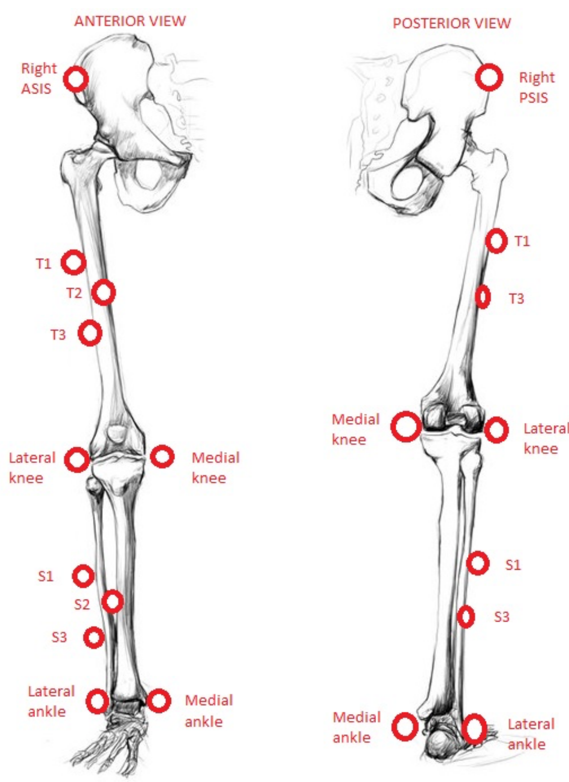
Problem 2
Complete Tutorial 2 (link below), and as you complete it, answer the questions that are listed below.
http://simtk-confluence.stanford.edu:8080/display/OpenSim/Tutorial+2+-+Simulation+and+Analysis+of+a+Tendon+Transfer+Surgery

a) What happens to the maximum moment of the wrist extensors if the ECU muscle is transferred to the ECRB?
b) What happens to the maximum moment of the ulnar deviators if the ECU muscle is transferred to the ECRB?
c) One goal of this tendon transfer surgery is to decrease excessive ulnar deviation. Has your simulated surgery achieved this goal? Explain.

Part II (K)

In the second part of this homework assignment you will be guided through the matrix calculations and analyses necessary to perform inverse kinematics and obtain knee joint angles from motion capture data.

Data has been collected on a subject performing a vertical jump, starting from a standing position and going down into a deep knee bend before leaping up. The marker positions on the right leg are approximately represented in the following diagram, where T1, T2, and T3 are markers for defining the local coordinate system (LCS) of the thigh and S1, S2, and S3 are markers for defining the shank LCS. All other markers are important for finding joint axes of rotation and anatomical coordinate systems (ACS), which are defined on an initial static trial. The static trial data for T1-3, S1-3, and the anatomical landmarks can be found in the **static_trial.mat** file, and the data giving the motion of T1-3 and S1-3 during the dynamic trial can be found in the **dynamic_trial.mat** file (the video for this trial is on Canvas to help you visualize what's going on). Both files are on Canvas (download the "HW5_data" zipped folder). When you load the ".mat" files, you will see a list of defined come up in your workspace. Each marker has three columns of data that correspond to the global X, Y, and Z position of that marker at each time point. Note that the static trial only has one time point, and the dynamic trial has many time points.



1. Based on the static trial, write MATLAB code that will use marker positions to **derive the 4x4 transformation matrix ($_{LCS.shank}^{GCS}\boldsymbol{T}$).** This matrix expresses the Local Coordinate System (LCS) of the shank with respect to the Global Coordinate System (GCS).
    - Marker *S2* is used as the LCS <u>origin</u>.
    - The <u>x-axis</u> is directed from marker *S2* to marker *S1*.
    - The <u>y-axis</u> is normal to the x-axis and the vector from marker *S2* to marker *S3*.
    - The <u>z-axis</u> is normal to both the x-axis and the y-axis.

2. Based on the static trial, write MATLAB code that will use marker positions to **derive the 4x4 transformation matrix ($_{ACS.shank}^{GCS}\boldsymbol{T}$).** This matrix expresses the Anatomic Coordinate System (ACS) of the shank with respect to the Global Coordinate System.
    - The <u>origin</u> for ACS.shank is the midpoint between the markers for *Lateral knee* and *Medial knee*.
    - The <u>z-axis</u> is directed from the origin towards the midpoint between markers denoting *Lateral ankle* and *Medial ankle*.
    - The <u>y-axis</u> is directed anteriorly and is normal to the z-axis and a vector from markers *Lateral knee* to *Medial knee*.
    - The <u>x-axis</u> is normal to both the z-axis and the y-axis and is directed medially.

3. Based on the static trial, write MATLAB code that will use marker positions **to derive the 4x4 transformation matrix ($_{LCS.thigh}^{GCS}\boldsymbol{T}$).** This matric expresses the Local Coordinate System of the thigh with respect to the Global Coordinate System.
    - Marker *T2* is used as the LCS <u>origin</u>.
    - The <u>x-axis</u> is directed from marker *T2* to marker *T1*.
    - The <u>y-axis</u> is normal to the x-axis and the vector from marker *T2* to marker *T3*.
    - The <u>z-axis</u> is normal to both the x-axis and the y-axis.

4. Based on the static trial, write MATLAB code that will use marker positions **to derive the 4x4 transformation matrix ($_{ACS.thigh}^{GCS}\boldsymbol{T}$).** This matrix expresses the Anatomic Coordinate System of the thigh with respect to the Global Coordinate System.
    - The <u>origin</u> for ACS.thigh is the midpoint of markers *Right ASIS* and *Right PSIS*.
    - The <u>z-axis</u> is directed from the origin towards the midpoint between the markers for *Lateral knee* and *Medial knee*.
    - The <u>y-axis</u> is directed anteriorly and is normal to the z-axis and a vector from markers *Lateral knee* to *Medial knee*.
    - The <u>x-axis</u> is normal to both the z-axis and the y-axis and is directed medially.

5. Use your answers to problems 1 and 2 to **derive the 4x4 transformation matrix that expresses the ACS.shank with respect to the LCS.shank ($^{LCS.shank}_{ACS.shank}T$).** Note that we will assume that this transformation matrix will not change during movement and can be used during the dynamic trials.

6. Use your answers to problems 3 and 4 to **derive the 4x4 transformation matrix that expresses the ACS.thigh with respect to the LCS.thigh ($^{LCS.thigh}_{ACS.thigh}T$).** Note that we will assume that this transformation matrix will not change during movement and can be used during the dynamic trials.

7. Based on the dynamic trial, write MATLAB code that does the following things:

   7a. Calculates the 4x4 transformation matrix ($^{GCS}_{LCS.thigh}T$) at each time point during the dynamic trial.

   7b. Calculates the 4x4 transformation matrix ($^{GCS}_{LCS.shank}T$) at each time point during the dynamic trial.

   7c. Calculates the 4x4 transformation matrix ($^{ACS.thigh}_{ACS.shank}T$) at each time point during the dynamic trial (note you will use your answers to problems 5 and 6 for your calculations).

8. Based on 7c, find and plot knee flexion angle α, the knee varus/valgus angle β, and the internal rotation angle γ using a Z-Y-X or X-Y-Z Euler angle convention. Provide your answers in degrees vs. time (sec). Do these angles make sense for the action described? Explain.

To Submit Online:

1. ONE homework document as a .pdf that includes:

- Answers to Part I: Problems 1 & 2
- Printouts of matrices from Part II: Problems 1-6.
- Plot of angles over time and explanation for Part II: Problem 8
- Part II MATLAB code (printed out) – please comment your code! If you don't adequately explain your coding process with the use of comments, it will be difficult/impossible for us to give partial credit for incorrect answers.

2. Part II MATLAB code (.m file(s)) submitted on CANVAS