Part I

Problem 1 :

a) The model has in total 23 degrees of freedom as per the coordinate list.

Following is the list of joints along with their anatomical planes in which the movement occurs:

1. Hip : Flexion (Sagittal)
   Adduction (Frontal)
   Rotation (Transverse)
2. Ankle : Angle (Sagittal)
3. Subtular : Angle (Transverse)
4. Metatarsophalangel : Angle (Sagittal)
5. Knee : Angle (Sagittal)

The lumbar movements are quite simplified as we ~~change~~ can observe that as we change the angle of extension, bending, and rotation, the bones in the spine do not move relative to each other. The movement for these angles just takes place about the pelvic and we can see any relative motion between the bones of spine. Also, the pelvic motion about the three planes looks simplified as angle changes as we see the complete structure moves as we change the angle. Generally, we can say that the model does not take into account the variation of flexibility among people, such as, age and so all motions have been simplified.

b) The muscles in the model that are represented with multiple lines of action are:

1. Gluteus medius
2. Gluteus minimus
3. Gluteus maximus
4. Adductor magnus

These muscles are represented in this way because different fibers within each muscle are aligned in different directions. Also, the different lines of action impact different parts of the body and representing the whole muscle as one line of action would be inaccurate.

c) The rectus femoris moment arm curve peaks at a knee angle of -25 degrees with a moment arm of 0.05 Nm.

The vastus intermedius moment arm curve peaks at a knee angle of -0.505 degrees with a moment arm of 0.048 Nm.

d) In the crouching gait, we can observe that the leg is never fully flexed at the moment the heel strikes. Also, ~~the knee~~ at the toe-off position, the knee does not fully flex back. In addition, the crouching gait has more swing than normal gait; the hips are forced to rotate more and feet move around the body. The knees pull to the inside and patient walks

→

with excessive knee flexion and a reduced range of knee joint motion. Quantitatively, the crouch gait has significantly higher knee angle because as the knee has to bend in order to maintain the crouched position. Also, for the same reason, there is less variation in knee angle during the crouch gait.

Problem 2:

a) Maximum moment of the wrist extensors, after the ECU muscle is transferred to the ECRB, ~~is~~ is increased. As one of the goals of the surgery is to increase wrist extension strength.

b) The maximum moment of the ulnar deviators is decreased after the ECU muscle is transfered to the ECRB. The new maximum moment occurs at 35 degrees deviation angle of the wrist.

c) By decreasing the overall moment in the wrist, ~~the overall strength of deviato~~ the goal of this tendon transfer surgery i.e to decrease excessive ulnar deviation is achieved.

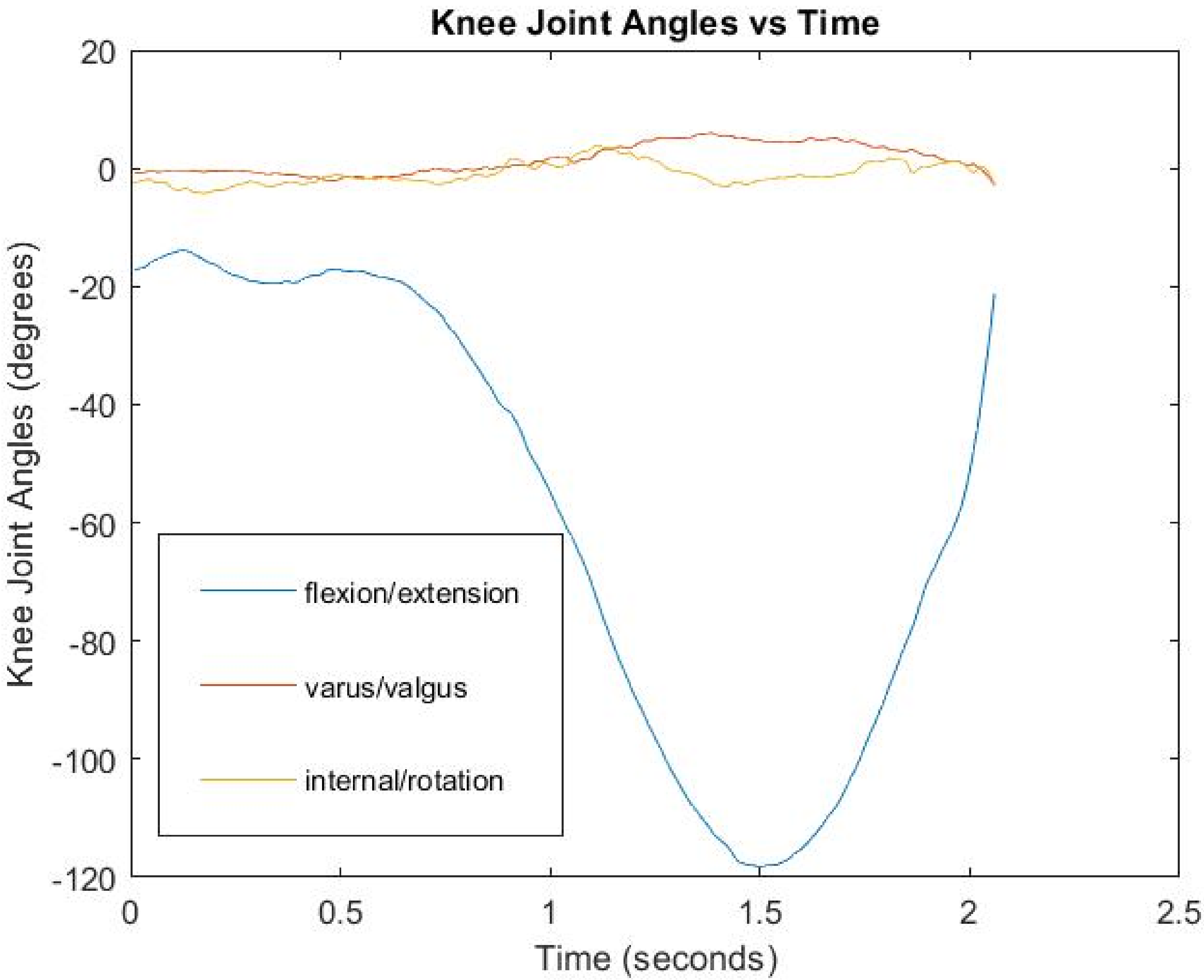
```
Transformation matrix that expresses LCS of shank wrt GCS

T_lcs_gcs_shank =

   -0.6915    0.6655   -0.2809  331.8686
    0.5673    0.7410    0.3592  472.3892
    0.4472    0.0891   -0.8900  283.1944
         0         0         0    1.0000

Transformation matrix that expresses ACS of shank wrt GCS

T_acs_gcs_shank =

    0.9997    0.0120    0.0228  350.1551
   -0.0141    0.9952    0.0970  495.8367
    0.0215    0.0973   -0.9950  493.3051
         0         0         0    1.0000

Transformation matrix that expresses LCS of thigh wrt GCS

T_lcs_gcs_thigh =

   -0.6504    0.6598   -0.3764  328.6312
    0.6865    0.7227    0.0804  452.4911
    0.3251   -0.2061   -0.9230  675.8262
         0         0         0    1.0000

Transformation matrix that expresses ACS of thigh wrt GCS

T_acs_gcs_thigh =

   1.0e+03 *

    0.0010   -0.0000    0.0000    0.3313
    0.0000    0.0010   -0.0002    0.6090
    0.0000   -0.0002   -0.0010    1.0399
         0         0         0    0.0010

Transformation matrix that expresses ACS of shank with respect to the LCS of shank

T_acs_lcs_shank =

   -0.6897    0.5998   -0.4057   94.6204
    0.6568    0.7541   -0.0016   48.2641
   -0.3050    0.2675    0.9140 -183.7069
         0         0         0    1.0000

Transformation matrix that expresses ACS of thigh with respect to the LCS of thigh
```

```
T_acs_lcs_thigh =

   -0.6205    0.6208   -0.4791  224.0077
    0.6746    0.7341    0.0775   39.8322
   -0.3998    0.2751    0.8743 -324.4638
         0         0         0    1.0000

>>
```

Part II

Problem 8:

The angles makes sense because while performing a vertical jump, starting from a standing position and going down into a deep knee bend, your flexion/extension angle should go into more changes with respect to time. You ~~want~~ would want to reduce your internal rotation about the hip or the amount of pelvic tilt, because if these angles increase, it may cause the roof of the acetabulum to drop down. This reduces the available range of motion in hip flexion and may be the reason that the subjects feel tightness or pinching in the hip while jumping. Therefore, the changes in flexion angle wrt time as well as changes in internal and valgus angle wrt time are justified.



Knee Joint Angles vs Time
Knee Joint Angles (degrees)
Time (seconds)
20
0
-20
-40
-60
-80
-100
-120
0
0.5
1
1.5
2
2.5
flexion/extension
varus/valgus
internal/rotation

This code is for conducting static trials

```
clc;clear;
load('static_trial.mat')
```

Problem 1

```
o_lcsshank = S2; % marker S2 as the LCS origin
x_lcsshank = (S1 - S2)/norm(S1 - S2); % x-axis directed from marker S2 to S1
y_lcsshank = cross((S3 - S2), x_lcsshank)/norm(cross((S3 - S2), x_lcsshank)); % y-axis
z_lcsshank = cross(x_lcsshank, y_lcsshank)/norm(cross(x_lcsshank, y_lcsshank)); % z-axis

R_lcs_gcs_shank = [x_lcsshank' y_lcsshank' z_lcsshank']; % Rotation matrix of LCS shank

% Transformation matrix that expresses LCS of shank wrt GCS
disp('Transformation matrix that expresses LCS of shank wrt GCS')
T_lcs_gcs_shank = [R_lcs_gcs_shank o_lcsshank'; [0 0 0] 1]
```

Problem 2

```
o_acsshank = (LAT_KNEE + MED_KNEE)/2; % origin of ACS shank
mid_ankle = (LAT_ANKLE + MED_ANKLE)/2;
z_acsshank = (mid_ankle - o_acsshank)/norm(mid_ankle - o_acsshank); % z-axis
y_acsshank = cross((MED_KNEE - LAT_KNEE), z_acsshank)/norm(cross((MED_KNEE - LAT_KNEE), z_acssl
x_acsshank = cross(z_acsshank, y_acsshank)/norm(cross(z_acsshank, y_acsshank)); % x-axis

R_acs_gcs_shank = [x_acsshank' y_acsshank' z_acsshank']; % Rotation matrix of ACS shank

% Transformation matrix that expresses ACS of shank wrt GCS
disp('Transformation matrix that expresses ACS of shank wrt GCS')
T_acs_gcs_shank = [R_acs_gcs_shank o_acsshank'; [0 0 0] 1]
```

Problem 3

```
o_lcsthigh = T2; % origin of LCS thigh
x_lcsthigh = (T1 - T2)/norm(T1 - T2); % x-axis
y_lcsthigh = cross((T3 - T2), x_lcsthigh)/norm(cross((T3 - T2), x_lcsthigh)); % y-axis
z_lcsthigh = cross(x_lcsthigh, y_lcsthigh)/norm(cross(x_lcsthigh, y_lcsthigh)); % z-axis

R_lcs_gcs_thigh = [x_lcsthigh' y_lcsthigh' z_lcsthigh']; % Rotation matrix of LCS thigh

% Transformation matrix that expresses LCS of thigh wrt GCS
disp('Transformation matrix that expresses LCS of thigh wrt GCS')
```

```
T_lcs_gcs_thigh = [R_lcs_gcs_thigh o_lcsthigh'; [0 0 0] 1]
```

Problem 4

```
o_acsthigh = (ASIS + PSIS)/2; % origin of ACS thigh
mid_knee = (LAT_KNEE + MED_KNEE)/2;
z_acsthigh = (mid_knee - o_acsthigh)/norm(mid_knee - o_acsthigh); % z-axis
y_acsthigh = cross((MED_KNEE - LAT_KNEE), z_acsthigh)/norm(cross((MED_KNEE - LAT_KNEE), z_acstl
x_acsthigh = cross(z_acsthigh, y_acsthigh)/norm(cross(z_acsthigh, y_acsthigh)); % x-axis

R_acs_gcs_thigh = [x_acsthigh' y_acsthigh' z_acsthigh']; % Rotation matrix of ACS thigh

% Transformation matrix that expresses ACS of thigh wrt GCS
disp('Transformation matrix that expresses ACS of thigh wrt GCS')
T_acs_gcs_thigh = [R_acs_gcs_thigh o_acsthigh'; [0 0 0] 1]
```

Problem 5

```
% Transformation matrix that expresses ACS of shank with respect to the LCS of shank
disp('Transformation matrix that expresses ACS of shank with respect to the LCS of shank')
T_acs_lcs_shank = inv(T_lcs_gcs_shank)*T_acs_gcs_shank

%save('T_acs_lcs_shank')
```

Problem 6

```
% Transformation matrix that expresses ACS of thigh with respect to the LCS of thigh
disp('Transformation matrix that expresses ACS of thigh with respect to the LCS of thigh')
T_acs_lcs_thigh = inv(T_lcs_gcs_thigh)*T_acs_gcs_thigh

% Saving the variables for using in dynamic trials
save('partc', "T_acs_lcs_shank", "T_acs_lcs_thigh")
```

This code is for conducting dynamic trials

```
clc;clear;
load('dynamic_trial.mat')
```

Problem 7

```
% Loading the saved variable file
load('partc')

% Initialization of vectors of knee joint angles
flex_extn_angle_phi = zeros(247,1);
varus_valgus_angle_theta = zeros(247,1);
int_ext_psi = zeros(247,1);

% for loop for generating the transformation matrices over the time step
for i = 1:length(time)

    % Declaration of variables for thigh
    o_lcsthigh = T2(i, :);
    x_lcsthigh = (T1(i, :) - T2(i, :))/norm(T1(i, :) - T2(i, :));
    y_lcsthigh = cross((T3(i, :) - T2(i, :)), x_lcsthigh)/norm(cross((T3(i, :) - T2(i, :)), x_l
    z_lcsthigh = cross(x_lcsthigh, y_lcsthigh)/norm(cross(x_lcsthigh, y_lcsthigh));

    R_lcs_gcs_thigh = [x_lcsthigh' y_lcsthigh' z_lcsthigh'];

    % Transformation matrix from LCS to GCS for thigh at each time step
    T_lcs_gcs_thigh = [R_lcs_gcs_thigh o_lcsthigh'; [0 0 0] 1];

    % Declaration of variables for shank
    o_lcsshank = S2(i, :);
    x_lcsshank = (S1(i, :) - S2(i, :))/norm(S1(i, :) - S2(i, :));
    y_lcsshank = cross((S3(i, :) - S2(i, :)), x_lcsshank)/norm(cross((S3(i, :) - S2(i, :)), x_l
    z_lcsshank = cross(x_lcsshank, y_lcsshank)/norm(cross(x_lcsshank, y_lcsshank));

    R_lcs_gcs_shank = [x_lcsshank' y_lcsshank' z_lcsshank'];

    % Transformation matrix from LCS to GCS for shank at each time step
    T_lcs_gcs_shank = [R_lcs_gcs_shank o_lcsshank'; [0 0 0] 1];

    % Transformation matrix from ACS shank to ACS thigh at each time step
    T_acsshank_acsthigh = inv(T_acs_lcs_thigh)*inv(T_lcs_gcs_thigh)*T_lcs_gcs_shank*T_acs_lcs_s

    %%%% Joint Angles

    flex_extn_angle_phi(i) = atan2d(T_acsshank_acsthigh(3,2), T_acsshank_acsthigh(3,3));
    varus_valgus_angle_theta(i) = atan2d(-T_acsshank_acsthigh(3,1), sqrt(T_acsshank_acsthigh(1,
    int_ext_psi(i) = atan2d(T_acsshank_acsthigh(2,1), T_acsshank_acsthigh(1,1));
```

```
end
```

Problem 8

```
% Plotting the Knee Joint Angles vs Time

plot(time, flex_extn_angle_phi)
xlabel('Time (seconds)')
ylabel('Knee Joint Angles (degrees)')
hold on
plot(time, varus_valgus_angle_theta)
plot(time, int_ext_psi)
title('Knee Joint Angles vs Time')

h = legend('flexion/extension', 'varus/valgus', 'internal/rotation');
rect = [0.15, 0.15, .30, .30];
set(h, 'Position', rect)
```