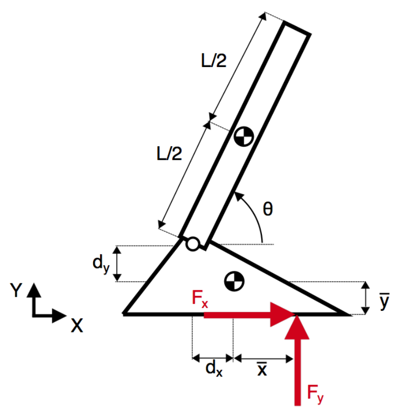
Homework 8 - BIOEN 440 / ME 445 - Spring 2016

1. Inverse Dynamics

In this problem you will apply inverse dynamics to a link segment model in order to relate ankle/knee moments/forces to known kinematics. The link segment model is shown in the figure. The two link model is composed of (1) foot link, and (2) shank link. The center of mass (COM) of each link is identified in the figure. The COM of the shank segment is located at the geometric center (L/2). The ankle joint is a horizontal distance of d_x and a vertical distance of d_y from the COM of the foot segment and at the distal end of the shank. The ground reaction force acts at a horizontal distance of $\bar{x}$ and vertical distance of $\bar{y}$ relative to the COM of the foot segment. The relative angle between the two segments is θ.

Besides the constants mentioned above, assume the following are known:

- $a_{1,x}$ - horizontal acceleration of the foot segment
- $a_{1,y}$ - vertical acceleration of the foot segment
- α_1 - angular acceleration of the foot segment
- m_1 - mass of the foot segment
- I_1 - moment of inertia of the foot segment
- $a_{2,x}$ - horizontal acceleration of the shank segment
- $a_{2,y}$ - vertical acceleration of the shank segment
- α_2 - angular acceleration of the shank segment
- m_2 - mass of the shank segment
- I_2 - moment of inertia of the shank segment
- F_y - vertical ground reaction force
- F_x - horizontal ground reaction force



Do/answer the following:

1. Draw a free body diagram for each segment (don't forget reaction forces/moments).
2. Apply Newton's second laws in each direction (don't forget rotation).
3. You should have 6 equations and 6 unknowns. Arrange your system of equations into matrix form:

$$A\mathbf{x} = b$$

where $\mathbf{x}$ is vector containing all unknown variables, A is the coefficient matrix containing known coefficient of your system of equations, and b is a vector containing known quantities.

4. How would you solve this matrix equation for unknowns $\mathbf{x}$?

2. Qualitative Gait Analysis

In this problem you will qualitatively analyze the ground reaction force (GRF) and the lower limb powers during walking. The data set for this problem contains:

- ground reaction force
- ankle power
- knee power
- hip power
- gait cycle vector

The data is an average of many steps for one leg. All powers are normalized by body weight, so the units are W/kg. The GRF is also normalized by body weight so the units are N/kg.

Do/answer the following:

1. Load in data set: `load('p2.mat')`
2. Plot the GRF and hip/knee/ankle powers on the same plot. **You must normalize all data to be between [-1,1] first.** To do this divide each variable by it's maximum absolute value. For example, for some variable F:

$$F_{norm} = F/\max(|F|)$$

   use `max` and `abs` MATLAB commands to help you do this. Now that the data is normalized you can plot on same figure (note: the units are now unitless).
3. At what point during the gait cycle does the foot leave the ground?
4. At what point during the gait cycle does peak ankle power occur? Why? Describe what is happing at this point.
5. Repeat (4) for the knee and hip.

3. Ankle Work

In this problem you will analyze the amount of work done by the ankle in the sagittal plane during gait. You will split this work into positive and negative work and compare the difference between each leg. Power and work are defined as follows:

$$P = \tau\omega \qquad W = \int_0^t P dt$$

The data set `p3.mat` contains left and right data for:

- normalized ankle power (W/kg)
- gait cycle vector

Do/answer the following:

1. Load the data into MATLAB (`load('p3.mat')`)
2. Calculate the negative and positive work of each ankle. To do this we must take the area under the negative/positive part of the power curve separately. These may be computed as follows:

$$P^- = \frac{1}{2}(P - |P|) \qquad P^+ = \frac{1}{2}(P + |P|)$$

   To calculate positive and negative work you must integrate each curve. Use the MATLAB command `trapz(x,y)`, where x is the time vector (in our case percent gait vector) and y is the curve you want to integrate.

3. Plot positive and negative power. Make one figure with two vertical subplots, one for left ankle and one for right ankle. On each plot, plot both positive and negative power (with different color traces). Use the MATLAB `area(x,y)` command to visually represent the amount of positive and negative work. The `area(x,y)` command will fill in the area above/below the curves. Use different colors for each area (e.g., `area(x,y,'FaceColor','r')` for red).

4. Report the following calculation in your solutions:
   - left/right positive work
   - left/right negative work
   - left/right net work: $W_{net} = W^{-} + W^{+}$

5. Compare left/right positive/negative work. Which ankle has the most positive work? Why? Which has the most negative work? etc.

4. Paper Review

Read the *unpowered exoskeleton* paper posted on the website. Give a brief one paragraph summary. Address the following:

1. What are the experimenters trying to test?
2. How did they test this?
3. Describe the difference test conditions.
4. What were the results?
5. What are the limitations of the study?