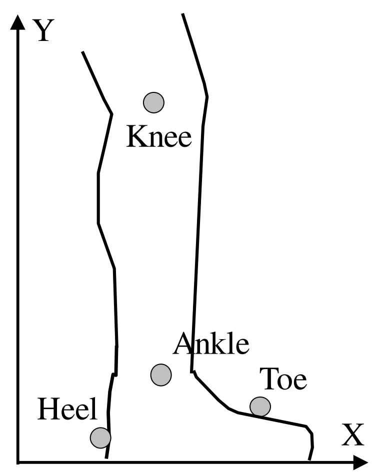
KIN 523 Winter 18
Homework Set 4 – Planar Kinematics Pavol

Due: 2/15/18

Answer the following problems.
You must show all work, including formulas used, numbers substituted, and answers with units.
If Excel was used, e-mail a copy of the workbook to me.
If a computer program was used, either attach or e-mail me a copy of the program.
Your written portion must indicate what equations were used in Excel and/or your program.

We used the motion capture system in the Biomechanics Lab to record a classmate's movements. We began by calibrating the motion capture system such that the global X axis was horizontal and the Y axis pointed vertically upward. A set of markers was attached to our participant. She then performed a static trial of 2 s of quiet standing, followed by several countermovement jumps. The participant faced in the +X direction during all trials (see figure). All trials were recorded at 120 frames/s.



The comma-delimited files "Static.csv" and "Jump.csv", posted on Canvas, contain the positions of selected markers during the static trial and during one of her jumping trials, respectively. The format of both files is as follows:

Column	Label	Description	Units
1	Frame	Frame number	frames
2	KNEX	Knee marker X position	m
3	KNEY	Knee marker Y position	m
4	ANKX	Ankle marker X position	m
5	ANKY	Ankle marker Y position	m
6	HEEX	Heel marker X position	m
7	HEEY	Heel marker Y position	m
8	TOEX	Toe marker X position	m
9	TOEY	Toe marker Y position	m

Based on the results of a residual analysis, the marker positions for the jumping trial have been low-pass filtered with a 4th-order, Butterworth, no-lag filter with a cut-off frequency of 18 Hz. You will now be performing a 2-D kinematic analysis in the sagittal plane.

1. *(0.4 pts)* During the static trial, what were the average X and Y positions of a) the heel marker and b) the toe marker? (You don't need to show your work for this one)

2. *(0.3 pts)* Compute the time that corresponds to each frame of data during the jumping trial, such that frame 0 corresponds to a time of zero.

3. *(1.5 pts)* Compute the segment angle of the foot as a function of time during the jumping trial. The angle of the foot is to be determined from the heel and toe markers (do not use the ankle marker). You must use the following convention:
   - The orientation of the foot during the static trial is defined to be a foot angle of 0°;
   - The foot angle > 0 for clockwise rotation of the foot from 0° in the figure on the previous page (*i.e.* toes pointed downward)

   You may need to modify the equation for segment angles presented in class.

   Furthermore, the angle you compute directly from the marker positions will differ from the actual foot angle (as defined above) by a constant offset. To answer this problem, you must first use the results of Problem 1 to compute an offset angle that can be used to determine the actual foot angles from the "measured" angles you compute from the marker positions.

4. *(0.9 pts)* Compute the segment angle of the leg as a function of time during the jumping trial. The angle of the leg is to be determined from the ankle and knee markers. You must use the following convention:
   - The longitudinal axis of the leg is defined to point from the ankle marker to the knee marker;
   - The leg angle is 0° when the leg's longitudinal axis points vertically upward (*i.e.* knee marker is directly above the ankle marker);
   - The leg angle > 0 for clockwise rotation of the leg's longitudinal axis from 0° in the figure on the previous page (*i.e.* forward inclination of the leg about the ankle).

   Again, you may need to modify the equation for segment angles presented in class.

5. *(0.6 pts)* From the measured ground reaction forces, it can be determined that take-off from the ground occurred at frame 128 and touchdown occurred at frame 181 during the jumping trial.

   On a single graph, plot the segment angle of the foot (from Problem 3) and the segment angle of the leg (from Problem 4) as a function of time (from Problem 2).

   Also mark the times of take-off and touchdown on your graph.

   Note: Be sure to include axis labels, units, and a legend (where appropriate) on all graphs.

6. *(0.8 pts)* Using the results of Problem 3, compute the angular acceleration of the foot segment as a function of time during the jumping trial, and graph the results. Use the "preferred formula", presented in class, for computing angular acceleration directly from orientation data. Follow the same sign convention as in Problem 3.

7. *(1 pt)* Using the results of Problems 3 and 4, compute the ankle angle as a function of time during the jumping trial, and graph the results. You must use the following convention:
   - An ankle angle of 0° corresponds to the relative orientation of the foot and leg in the anatomical position (*i.e.* when both segments are in their 0° orientation);
   - The ankle angle > 0 for ankle dorsiflexion from 0° (*i.e.* flexion)

   You will need to determine what equation is appropriate.

8. *(0.4 pts)* From the results of Problem 7, determine and report the following for the jumping trial:
   a. The peak ankle dorsiflexion angle
   b. The peak ankle plantarflexion angle
   c. The ankle range of motion

9. *(0.9 pts)* Using the results of Problem 7, compute and graph the angular velocity of the ankle as a function of time during the jumping trial. Follow the same sign convention as Problem 7.

   On the graph, clearly mark (at the time it occurs) and label:
   a. The peak ankle dorsiflexion velocity
   b. The peak ankle plantarflexion velocity

10. *(1.5 pts)* As noted earlier, take-off from the ground occurred at frame 128 and touchdown occurred at frame 181 during the jumping trial. Based on this information and the results of Problems 3, 7, and 9, describe:
    a. The angular motion of the foot
    b. The angular motion of the ankle joint

    over each of the following 3 periods:
    i. Before take-off
    ii. During flight (*i.e.* between take-off and touchdown)
    iii. After touchdown.

    Descriptions should convey the initial position, the general pattern of the directions and rates of motion over the period, and the final position. Use appropriate anatomical terminology.

11. *(1.7 pts)* Using methods similar to those you used to compute the ankle angle, the knee angle was computed for the same jumping trial. The following convention was used:
    - A knee angle of 0° corresponds to the relative orientation of the leg and thigh in the anatomical position (*i.e.* knee fully extended);
    - The knee angle > 0 for knee flexion from 0°.

    The comma-delimited file "KneeAng.csv", posted on Canvas, contains the resulting knee angles. The format of the file is as follows:

Column	Label	Description	Units
1	Frame	Frame number	frames
2	KneeAng	Knee angle	deg

    a. From these data and the results of Problem 7, construct an angle-angle diagram in which the knee angle is plotted against the ankle angle. On the diagram: i) draw arrows to show the progression of time, and ii) mark the points corresponding to the instants of take-off and touchdown (see Problem 10).

b. Based on the diagram from part (a), describe the coordination between motion at the ankle and knee over the course of the jumping trial. That is, for each part of the jumping motion:
   i. Initial downward countermovement
   ii. Push-off (*i.e.* end of the countermovement to take-off)
   iii. Flight (*i.e.* take-off to touchdown)
   iv. Landing (*i.e.* touchdown to end of downward motion)
   v. Return to standing

   describe whether the motions were approximately in phase, approximately 180° out of phase, somewhere in between, occurring primarily at the ankle, or occurring primarily at the knee.

Note:

- We will be using the results of Problems 3, 6, and 9 in later homework sets when we determine the joint moments and power being produced at the ankle during the jump.