

## **BME 315 Biomechanics**

### **Laboratory #3**

#### *Kinematic analysis of center of mass (COM) and joint movement*

### **Introduction**

As you learned in class, the analysis of human and animal motion can be done using motion capture techniques. There are two types of camera systems: a passive marker motion capture system and an active marker motion capture system. You should know the difference between these two types of systems. The basic concept of both techniques is the same. A series of cameras view markers that are placed on a person. Since the cameras only see in 2D, at least two cameras must be used in order to reconstruct 3D coordinates. The cameras are calibrated such that the software can combine data from multiple cameras to reconstruct a marker's x, y, and z position in 3D space (also known as the capture volume). You will never have to compute the 3D position of markers; the software will always do this for you. However, you can greatly affect the ability (or inability) of the software to accurately compute these positions. For example, what if a camera can't see a marker? Does the position of your cameras relative to the markers matter? What if you (or someone else) move the camera in the middle of your data collection?

You also learned in class that motion capture techniques are not only used for biomechanics. Only a small amount of income for the camera and software companies comes from research and clinical applications. The majority of users are companies that make movies, commercials, and video games. The accuracy of marker placement and joint motion is not nearly as great when animating human motion for football commercials as it is during gait analysis prior to surgery.

While some users are concerned with realistic looking movements in animations, we are interested in knowing precisely how humans move. It is up to you (with some help from your TAs) how you are going to make sure this happens. You will need to decide where to place the markers on yourself in order to obtain the most accurate joint angles as possible while still ensuring that the cameras can see the markers during your movements.

You will also be learning about how filtering position data affects velocity and acceleration calculations. In addition, one of the questions will double-check that you understand collisions of the human body (i.e. you jumping and landing on the floor).

### **Equipment**

For this lab, you will be using an active motion capture system (Visualeyez 3D motion tracking system, model VZ-4000, Phoenix Technologies Inc., [www.ptiphoenix.com](http://www.ptiphoenix.com)). We have one tracker unit, consisting of three cameras that are located a fixed distance apart. The system uses wireless infra-red diodes (LEDs) for sensing the position of the markers in space.

Here is a brief description of how the system will work for this lab (do not cut and copy this into your lab report):

1. A series of markers are connected to a battery pack, an antenna (to receive a synchronization signal from the camera unit), and a tracker control module (TCM). The type of TCM unit and how the markers are plugged into the TCM determine the names of the markers in the output file. In this lab, we are using TCM's 2 and 3 with respective markers 4-9 for each TCM. Therefore your markers will be called 204, 205, 206, etc. You must record what marker you put where on your body!

2. The markers are pulsed sequentially at a very high rate by the camera control unit. When pulsed, a marker emits light that is detected by each camera. The 3D coordinates of the marker are reconstructed from each camera's 2D view, and the coordinate data is stored. The sampling rate of the cameras can be changed. This is how frequently the position of a marker is sampled per second. For this lab, you will be capturing the marker position data at  $f=100\text{Hz}$ .
3. The software we are using is called, VZSoft v2.80. To collect data in during lab, we will simply press record and then stop. Whenever the record button is pressed, the markers appear on the computer screen as dots moving around in space. The resulting data will be exported into a \*.txt file by your TAs. This format is readable by spreadsheet software or by graphics software, e. g. KaleidaGraph.
4. The TAs will convert and reformat the \*.txt files into a format that you can more easily process in software packages, e.g. MATLAB.

Before you arrive for this lab, the coordinate system of the room was defined. The center of the room is located at the corner of the first metal plate on the floor, closest to the white board. Positive-x points from the white board towards the south wall (graduate student desks). Positive-y points from the hallway door towards the big wooden cabinets. Therefore, positive-z points up. If you walk from the white board to the south wall, you will be walking in the positive-x direction.

### **Testing**

1. Markers will be attached depending on the trial you are performing. For the jumping trial one marker will be attached to your center of mass (COM) using a Velcro belt. Make sure that the LEDs are facing outwards. With the LED facing the cameras, perform a vertical jump, just like you did in the previous lab.
2. Chose one of the following motions:
  - a. Walking
  - b. Running
  - c. Bicycling
  - d. Some motion of your choice.

Plates with attached markers are provided that will keep the markers in line with your upper and lower legs. Strap on the plates such that the black Velcro line is parallel or as close to parallel as possible with your femur (upper leg) and tibia (lower leg). Perform the activity, again making sure that the LEDs from the markers are always facing the cameras during your movement.

3. When you go home today, or on your way home, weigh yourself. You will need a fairly accurate mass to do some of the analysis questions.

### **Analysis**

#### *Filtering the Position Data*

1. Using the example code provided below, decide on an appropriate cutoff frequency to low-pass filter the marker position data. Depending on the activity you choose, you may want to filter your two trials at different frequencies. Use MATLAB for the filtering process. MATLAB is available in all CAE labs or can be tethered using the internet from home or anywhere on campus.

- a. This example code given below first opens a file located in the specified location and then saves the data in the workspace as a variable called “data”. The next line defines how you will filter your data. You should look up “butter” and “filtfilt” in the MATLAB help menu. Here, I used a 4<sup>th</sup> order filter with a cut-off frequency of 10Hz.
- b. After filtering the data, you can either continue working in MATLAB or export the filtered data to graphics or spreadsheet software. Graphics software KaleidaGraph facilitates preparation of good graphs. It is available on CAE computers.

```
data = load('C:\My Documents\jump.trc');
[b, a] = butter(4,10/(0.5*sample_rate), 'low');
filtered_data = filtfilt(b,a,data);
```

### *Jumping Trial*

1. Plot the vertical (z) positions of your center of mass during jumping from your standing upright position to the completion of your jump (after you land and then stand straight up again). On the same plot, plot the filtered data (using the frequency that you chose). Create a table of your starting position, squatting COM position, maximum jump height, and final squatting position when you land for both the filtered and unfiltered data. Get the same data from at least 2 others in your lab section and add that to your Table as a comparison.
2. Differentiate the z-positions of your center of mass to get upward velocity using the original unfiltered data. Create a table of the maximum and minimum velocities and the height (z-position) at which these occur. Repeat this process after low-pass filtering the data at 3, 6 and 12 Hz.
3. Calculate your center of mass acceleration using the filter cutoff frequency that you believe best reflects the actual movement. Plot the acceleration and pick the time on this plot when you think you landed.
4. Using the positions, velocities, and accelerations of your center of mass from the filtered data only, estimate the vertical force under your feet throughout the trial. Compare the estimated ground reaction forces with what you previously measured using the force plate in Lab 2.

### *In-plane Movement Trial*

1. Use the x and z positions of the markers during your chosen movement. Using only the filtered data, calculate the knee joint angles throughout this trial. Plot the joint angle vs. time. Be sure you use the same +/- convention as is standard for movement about that joint.

## **Discussion**

You should discuss something related to every topic in this lab. Some topics include, but are not limited to:

*Filtering* – There is noise in the position data. Where does the noise come from? What is a cutoff frequency and why did we tell you to filter your data using the low-pass filter that we did? How did the different low-pass filter frequencies change your results? Be sure to discuss the criteria you used to determine the best cut-off frequency to use for both movements.

*Marker Placement* – You chose where to place the markers for both trials. Why did you place the markers where you did and how did it affect your results? Consider finding out what biomechanics researchers do to improve the accuracy of their results.

*Ground reaction forces* – Why is this not the most accurate way of measuring forces during landing? What assumptions are inherent in this technique that causes discrepancies between the forces estimated in this lab and those determined with the force plate previously in Lab 2.

*Joint Angles* – Compare your joint angles to published data of other people doing the same activity.