ENGR 325	**Lab 5**	**Walla Walla University**
Winter 2021	**Video analysis and filtering**	**Inst. Mark Haun**

The goal of this lab is to obtain a position-time dataset from video analysis and create a Butterworth filter with appropriate smoothing to obtain useful velocity and acceleration graphs.

Objectives:

- Obtain useful 2D data from a video clip.
- Understand how digital filtering can increase the quality of results.
- Learn how the frequency content of a signal can inform the choice of filter cutoff frequency.

Procedure:

1. On the course website in the Lab 5 folder, you will find a video file showing a side view of a human vertical jump with markers indicating various joint centers, including at the hip. Download the video file and save it to your lab computer. Also download the Excel spreadsheet (butterworth vertical jump template).
2. Download and install the Tracker video-analysis tool from https://physlets.org/tracker/. Run Tracker and open the video file. (You can ignore the warning that pops up.)
3. The meter stick in the video has two markers which are 0.9 m apart. Use Track → New → Calibration Tools → Calibration Stick, then select the two markers and type in the spacing. This sets up the data scaling factor.
4. Use Track → New → Point Mass to initialize a data table. Make sure you are on the first frame. Digitize the hip marker position, frame by frame, for the entire jump. Each time you center the crosshairs on the hip marker and shift-click, the frame will advance automatically and the x,y coordinates will be added to the data table.
5. Copy and paste the position-time data (time and vertical coordinate Y) from Tracker into the Excel file.
6. Read the instructions embedded in the spreadsheet first. Then, process the position data in Excel by calculating velocity and acceleration using first central difference formulas found on the last page of this handout. The blue and green columns have started this for you. Update the graphs of position, velocity, and acceleration vs. time.
7. Finish the two stages of filtering (red columns—ask your instructor for help). Calculate velocity and acceleration of the smoothed data, and graph these along with the corresponding results from the raw data. Experiment by varying cutoff frequencies in the Butterworth filter to obtain an optimal amount of smoothing for the velocity and acceleration curves.
8. Take your raw position data to MATLAB and analyze it using Fourier methods to obtain a frequency distribution for the data set. Compare this frequency distribution graph to your decision about an optimal cutoff frequency for filtering of the data.

Report guidelines:

Be sure to include graphs of the raw and filtered position, velocity and acceleration data, which follow the departmental guidelines. It is nice to provide a grid, in which case both vertical and horizontal gridlines should be present (not just one or the other).

Include one or two paragraphs, in your own words, explaining what you did and any adaptations you had to make along the way. How did you end up choosing the filter cut-off frequency?

Formulas:

$$\begin{aligned}\text{Velocity at time index } i &= \dot{y}_i \approx \frac{y_{i+1} - y_{i-1}}{2\Delta t} \\ \text{Acceleration at time index } i &= \ddot{y}_i \approx \frac{y_{i+1} - 2y_i + y_{i-1}}{(\Delta t)^2}\end{aligned}$$

To filter discrete-time data y_i with a 2nd-order digital filter,

$$y'_i = a_0 y_i + a_1 y_{i-1} + a_2 y_{i-2} + b_1 y'_{i-1} + b_2 y'_{i-2}$$

where the $\{y_i\}$ are the raw data points (input) and the $\{y'_i\}$ are the previously filtered data points (output).

Digital Butterworth filter coefficients (2nd-order):

$$\begin{aligned}a_0 &= \frac{K_2}{1 + K_1 + K_2} \\ a_1 &= 2a_0 \\ a_2 &= a_0 \\ b_1 &= -2a_0 + K_3 \\ b_2 &= 1 - 2a_0 - K_3 = 1 - a_0 - a_1 - a_2 - b_1\end{aligned}$$

where

$$\begin{aligned}\omega_c &= \tan\left(\frac{\pi f_c}{f_s}\right) \\ K_1 &= \omega_c\sqrt{2} \\ K_2 &= \omega_c^2 \\ K_3 &= \frac{2a_0}{K_2}\end{aligned}$$

where f_c is the desired cutoff frequency and f_s is the sampling frequency.