Force Plate Lab

Overview

This lab is based upon an exercise science lab at University of Southern California[1]. Force plates similar to the ones we will be using today are commonly used in physical therapy clinics[2] to measure the forces that humans can exert. The force plate is essentially a bathroom scale that can read and record the normal force applied to it. In this case the plate will record data 100 times per second.

We will be using the data from the force plate and from a sonic ranger to understand the forces involved during a "counter-motion" jump. During a counter-motion jump, the subject will start from a standing position, and bend the knees before jumping. From this force graph, you should be able to understand the speed with which the person leaves the plate and predict the height which the jumper will achieve.

Materials

At each *table* you should have

- A force plate / sonic ranger setup. The force plate is on the floor while the sonic ranger is mounted on a pole.

Note that having one setup per table means that multiple teams will need to share the setup. However, EACH TEAM NEEDS THEIR OWN DATA! The data collection phase of the experiment should be quite quick so sharing should not be a problem.

What you need in your report – Due Friday 11 March

- Your graph from Captsone for Part A
- The answers to Questions 1 – 6
- Your graph from Captsone for Part D

Note, this is a long lab. You will need to stay focused to complete it on time!

[1] Dr. Jill L. McNitt-Gray, "USC EXSC 408L: Biomechanics Lab," *Biomechanics - EXSC 408L*. [Online]. Available: http://www.usc.edu/dept/LAS/kinesiology/exsc408l/. [Accessed: 06-Mar-2016].

[2] S. Golriz, J. J. Hebert, K. B. Foreman, and B. F. Walker, "The reliability of a portable clinical force plate used for the assessment of static postural control: repeated measures reliability study," *Chiropractic & Manual Therapies*, vol. 20, no. 1, pp. 1–6, 2012.

Part A – Collect data for the counter-motion jump

Procedure – Setup the equipment. Do this BEFORE starting to take data!

i. Select one team member to be the test subject
ii. Have the test-subject stand on the force plate
iii. Check the alignment of the motion sensor to
    a. Make sure that the test subject will not hit their head when they execute the counter motion jump!
    b. Make sure that the sensor is directly over the head of the person who will do the jump

   To adjust where the motion sensor is located on the cross-bar loosen the screw on the top of the motion sensor, slide it to the desired location, and then tighten it back down. You can also adjust the height by using the screw clamps to reposition the rods.

Procedure – Taking data

i. If you have not already, download the ForcePlate file from Moodle
ii. Start Pasco Captsone on one of the table computers
iii. Within Capstone, select "File → Open Experiment" and select the ForcePlate file. The result should be a window that looks like Figure 1

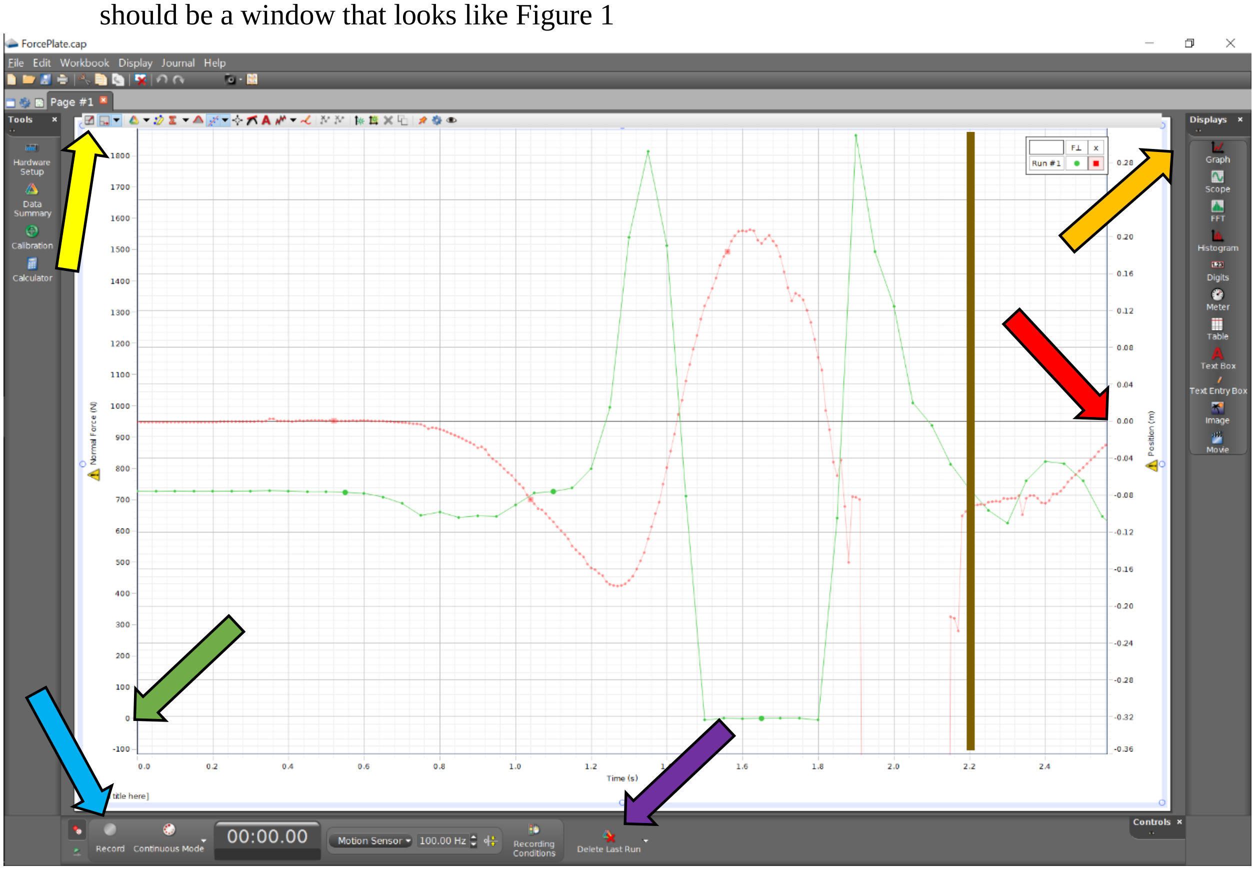

Figure 1: What Captsone should look like when opened correctly. The arrows indicate specific steps in the procedure. The thick gold line at t = 2.2s will be referenced in the instructions for interpreting this graph.

iv. Connect the sonic ranger and the force plates to the laptop via the USB ports.
v. Click "Delete Last Run" by clicking the button under the purple arrow

vi. Have the test subject stand on the force plate. Have another team-member push “Record” by clicking the button under the blue arrow.

vii. Have the test-subject remain stationary until data begins to appear. Then, have the test subject execute the counter-motion jump. When done, press “Record” again to stop taking data.

What you should have at this point

The result will be two graphs, one for the normal force exerted on the force plate and the other for the position of the test subject’s head. A position of zero is when the person is just standing still. Negative distances are further away from the sensor while positive distances are towards the sensor. Both are graphs as functions of time and share a horizontal time axis. To read the force at a given instant, use the axis on the left. To look at the position for a given time, use the axis on the right. **NOTE, the zeros for each axis will probably be in different places!** In the example data of Figure 1, the zero of the force plot (green data points) is indicated by the green arrow, while the zero of position (red data points) is indicated by the red arrow.

To make your graph easier to read and to save

i. You get a good zoom for your data by clicking the button under the yellow arrow.

ii. You can zoom an axis by doing a click-and-drag on it. Note, you can zoom the force and position vertical axes separately.

iii. TO SAVE YOUR PLOT: You can copy the graph by right clicking on the blue line indicated by the orange arrow above. This right-click will yield a menu where you can copy the graph and then paste it into an email or MS Word. **YOU MUST INCLUDE A PRINTOUT OF YOUR GRAPH WITH YOUR REPORT!**

Part B – Interpreting the counter-motion jump graph[3]

There are various stages to a counter-motion jump which we will label A – L. Some stages are a range of times while others are an instant:

- Stage A. The jumper is upright and stationary
- Stage B. The jumper relaxes the leg and hip muscles and the jumper begins to accelerate downwards.
- Stage C. The jumper begins to activate the leg muscles.
- Stage D. The activation of the leg muscles has now reached a stage where the jumper is still moving downwards but the downwards speed is getting closer to zero.
- Stage E. The lowest point of the jump. Note that this is a point in time, not a range!
- Stage F. The push-off phase where the jumper is moving upwards.
- Stage G. The jumper reaches maximum speed. Note that this is an instant in time, not a range.
- Stage H. The jumper is still in contact with the plate but has begun to lose speed due to gravity.
- Stage I. The jumper has left the force plate. Note that this is an instant in time, not a range.
- Stage J. The jumper is at the peak of the jump. Note that this is an instant in time, not a range.
- Stage K. The jumper has landed. Note that this is an instant in time, not a range.
- Stage L. The jumper comes to a stop by bending their knees. For this portion ignore the oscillations and just look until the force registered is equal to the weight again. In Figure 1, the end of Stage L is indicated by the thick gold line in Figure 1.

Question 1:

Draw a sketch of the jumper in each stage. **THIS IS HARD! DO THIS ON THE WHITEBOARDS SO THAT THE INSTRUCTIONAL TEAM CAN HELP YOU!** You can then copy the results to your report. Your sketch should include:

- A rough sketch of what the jumper looks like (Figure 2 provides some *examples* – not all positions are referenced!).
- The direction of the velocity as an arrow
- The direction of the acceleration as an arrow
- A qualitatively correct FBD, i.e. if the weight is larger than the normal force at an instant then it should be drawn with a longer arrow.

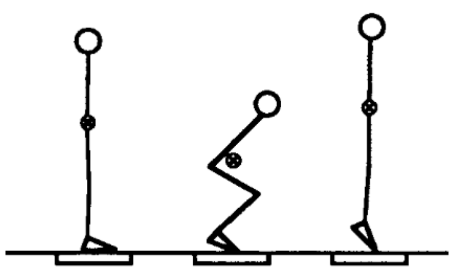

Figure 2: Sketches of what the jumper could look like. You should have one sketch for each stage and your sketches should include the direction of v, the direction of a, and a FBD of the jumper.

Question 2:

Identify the time interval for each stage on your graph.

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[3] N. Linthorne. *Analysis of Standing Vertical Jumps using a Force platform.* Am J. Phys. **69** (11), November 2001. DOI: 10.1119/1.1397460. https://www.brunel.ac.uk/~spstnpl/Publications/VerticalJump%28Linthorne%29.pdf.

Part C – Thinking about the net force

<u>Question 3:</u>
The impulse momentum theorem

$$\vec{J} = \Delta\vec{p}$$

Connects the *net* force to the change in momentum of the object. Your graph is only of the normal force. What do you need to do to get the net force for each instant in time? Answer in a sentence or two. If you need some other piece of data, how could you get it from your graph? Have a member of the instructional team check you out before you proceed!

Part D – Have Capstone display the net force

It is possible to have capstone display the net force.

Procedure

The procedure is very similar to Part A – Taking Data described on page 2. The only difference is in step vii. Have a third team-member push the "tare" button next to where the cord attaches after data taking begins but before the jumper begins to jump. The result will be a graph of the net force. **YOU MUST INCLUDE THIS GRAPH IN YOUR REPORT!**

<u>Question 4 (Do-able outside of class):</u>
Explain why what you see on the graph is consistent with your answer Question 3.

Part E – Calculate the launch speed of the jumper using the F(t) graph

<u>Question 5:</u>
Estimate the impulse from your graph for part D and use it to determine the launch speed of the jumper. Shade on your graph which area you will use. You may want to talk through your procedure with a member of the instructional team before proceeding.

Part F – Forces upon landing (can do at home)

<u>Question 6:</u>
Describe why bending your knees when you land is beneficial in terms of the impulse-momentum theorem. Say the average force needed to bring you to a stop when you bend your knees is *F* Newtons. How what would the average force be, in terms of *F*, if you landed stiff-legged and came to a stop in $^{1}/_{10}{}^{th}$ the time?