Motion 1

Equipment: Capstone, motion sensor mounted about 30 cm above lab bench, blue motion sensor, and MatchGraph software.
Lab Report: Describe procedures not given in the write up. Submit data graphs where asked. Label your work with the section number and your lab partners name.

1 Introduction

In part 1 of this lab you will learn how to set up Capstone for the motion sensor and digits display. Also, the motion of a notebook that you move with your arms will be examined as will various aspects of the digits display. This is the first lab using Capstone, so the instructions will be more detailed than they will be in future labs. Please remember the procedures for configuring the motion sensor properties, digits display set up window, input menu, and any other relevant operations.

In Part 2 of this lab you will be running MatchGraph. Match Graph uses the same Pasco hardware. You will analyze various curves of position vs time and curves of speed vs time. The speed and position will be determined by moving flat surface object (notebook, tablet, etc) in front of the motion sensor. Your task is to move the object so that your data follows the presented curves as closely as possible. IMPORTANT: Before doing the experiments, look at the curves and infer what motion you must impart to the notebook so that your data closely matches the curves!

2 The Motion Sensor

The motion sensor uses sound waves to detect the distance of an object. Sound is a pressure wave that travels with a certain speed, depending on the type and temperature of the gas it is traveling in. For air at 20° C the speed is approximately 343.6 m/s.

Like all wave phenomena, sound can be reflected (echos). The motion sensor not only sends out the pulses but also detects the reflections.

The motion sensor emits short sound pulses, each traveling at the speed of sound. The pulses are equally spaced in time, and the number of pulses emitted per unit time is called the sample rate. The sample rate gives the number of positions measured per second. It can be varied from 1 per second to 250 per second. The unit of "per second" is called a Hertz, or Hz for short. The default sample rate is 20 Hz. The pulses are ultrasonic (you cannot hear them), but you can hear clicks. The motion sensor also detects the reflected pulses and measures the time between the emission and reflection of a given pulse. The Capstone digits

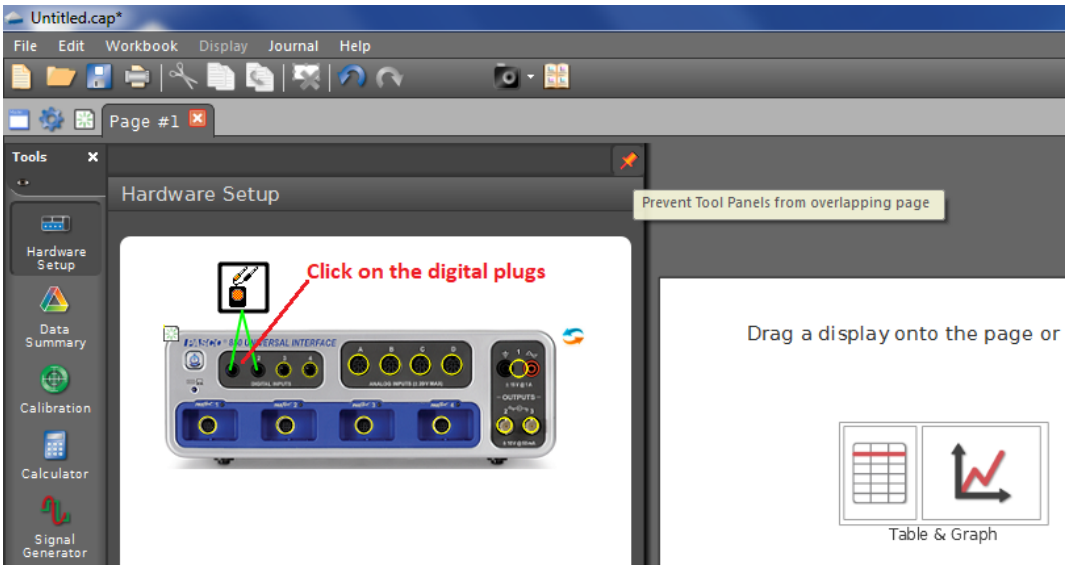
display used can be programmed to give the ping echo time, distance from the motion sensor, velocity, and acceleration. Only the ping echo time is measured. The other quantities are calculated by Capstone.

There are two types of motion sensors that you will be using throughout the semester. The blue motion sensor has a single cable that connects to passport plugs 1, 2, 3, or 4. The black motion sensor is a 2 plug digital sensor. The yellow plug carries the transmitted signal and is inserted into channel 1 of the interface, and the black plug is inserted into channel 2 and detects the echo. The maximum distance that can be measured by theses sensors depends on the sample rate. Both sensors have a switch which allows you to choose between a pulse emitted in a narrow or somewhat broader cone. Choose the switch position that gives the best results.

3 Part 1

3.1 Programming Capstone

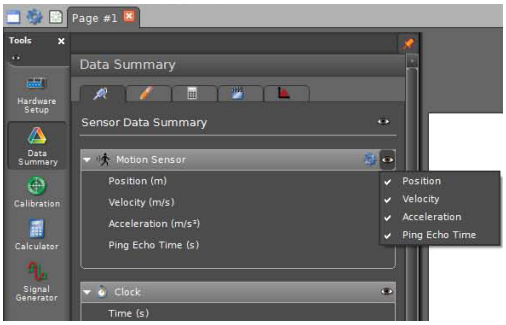
To program Capstone for the motion sensor, open Capstone by double clicking on icon from the desktop. When the program opens go to the sidebar on the left, choose the tab "Hardware Setup." The Pasco 850 interface should come up in the hardware setup window. Typically, the next step would be to select the input on the interface that the sensor is plugged into. For this experiment we're using a motion sensor, so click on the digital input channel 1 that the black sensor is plugged into and scroll down to **Motion Sensor II**. If all is well then you should see the hardware setup window and an active motion sensor.



Note: You can adjust the size of a window by clicking on the orange tack located in its top, right corner. This will help prevent overlapping.

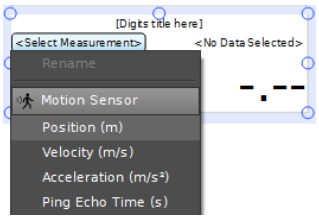
In the tools menu located on the left click on **Data Summary.** In the top right corner of the Motion Sensor II box, click on the small eye and select **Ping Echo Time**. You should

now see Position, Velocity, Acceleration, and Ping Echo Time all checked on. Look at the following illustration, for guidance.



At the bottom, center of the screen, to the right of the stop clock, is the sample rate. The default sample rate is set to 20 Hz. Changing the sampling rate adjusts the number points being measured per unit time. If you increase the sampling rate the number points recorded increase per unit time. Vary the sampling rate as you please.

Next step is to open a digits display. The **Digits** box is located in the **Displays** menu on the right side of the screen. Click and drag the digits box onto the white part of the center screen. Click on **Select Measurement** and select **Position.** (The m in the parentheses means the units are meters.)



Note: You can change the unit of measurement in the digits box by clicking on the little (m) in parentheses.

To have a better feel for Capstone try the following

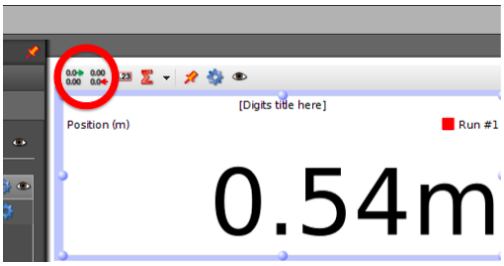
- Move the digits display window by clicking and dragging the center of the digits box.
- See if you can enlarge the digits display window by dragging an edge or a corner. You should be able to enlarge the display and this will be useful.
- On the digits display window you can increase and decrease the number of digits being displayed by clicking on the two top boxes located on the top left.
- Next try adding a Velocity Digits display. In order to add different digits displays, click and drag another digits box to the center window and click on select measurement as you have done before. **Repeat for Acceleration and Ping Echo Time. What are all the units of measurements and dimensions for position, velocity, acceleration, and time?** When you're done getting a feel for the software close all

the displays except Position by right clicking on the digits display box and selecting Delete.

What is the speed of sound? Can you think of why it might vary from day to day?

3.2 Measuring Position

This should be done for you, but if not mount the motion sensor so that it is on one side of the lab bench and about 30 cm above the bench. Make sure the blue motion sensor is disconnected. Place a meter stick on the bench with one end in the plane of the sensor grill and hold a flat surface object in your hands. Have your partner click the record button in the lower left side of the experiment set up window and examine the digits display and meter stick while you move the notebook in the acoustic beam of the sensor. Click the STOP button when finished. Then click on **Data Summary**. Run#1 appears in the digits display and in the Sensor Data Summary box. Keep in mind the digits display shows the last value measured. To change to the previous data you need to click on where it says run in the upper right corner of the digits display box. To increase or decrease the number of digits to the right of the decimal point, click on one of the top two left corner buttons of the digits display. Look at the image below.



How many significant figures do you need? You're the experimenter explain your logic. Whatever you decide adjust your digits display Take another run and see how close you can get the notebook to the sensor and obtain reliable values.

Try deleting Run # 1 by clicking on it in the sensor data summary window and clicking on the red X. Don't let too many runs accumulate.

3.3 Checking on Capstone

It is a good idea to see if the equipment is working as it should. For example, if I were an MD and about to declare someone brain dead, I might as well put the electrodes on my own head to be sure that the machine was OK. Here we will check up on Capstone.

- Set up a stationary stable reflector about 0.8 m in front of the motion sensor.
- Open digits displays, for **Position** and for the **Ping Echo Time.** Measure the position and the Ping Echo Time to 3 significant figures.

- Then, use the speed of sound and the ping echo time to find the calculated value of position.

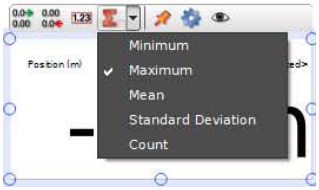
Compare your calculated value to the value given in one of the digits displays for position in Capstone. **When compared to the meter stick how off are your values? What the motion sensor actually measures is the round trip pulse time. Does Capstone calculate the distance accurately?**

3.4 Measuring Velocity

Add velocity to the digits display and take another run, see what happens as you move your notebook in various ways. **In the digits display what does a minus sign signify? If a minus sign is missing then what is occurring to the motion?**

3.5 Doing statistics on velocity

Carry out an experiment to see how fast you can move your notebook toward and away from the sensor. Hint: Click the down arrow button in the digits display and select statistics. You need to click on the sigma button to select the Maximum velocity. Repeat for Minimum, Mean, and Standard Deviation.



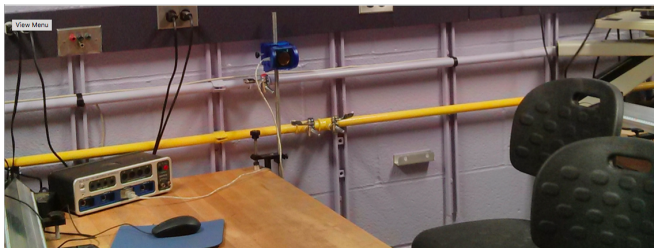
Now you need to determine who has the steadier hand. Hold the notebook at 1.1 meters from the motion sensor. Select Standard Deviation for position. **Explain why we use standard deviation?** Now, have your partner do the same. **Between you and your partner, whose pulse is steadier?**

Why would a sample rate of 20 Hz work for this part of the experiment? You can change it if you want. To do so, go to the bottom center of the Capstone software. You can adjust the sample rate of each individual sensor.

4 Part 2

4.1 The Capstone Experiments

Capstone has many experiments. Now, you will be using the **Motion Graph Matching** experiment. The file is located on the desktop display. **Note: You need to close your current capstone display before opening the motion graph matching file.** Also, you will be using the **blue motion sensor** which needs to be plugged into a passport. As illustrated below, mount and position the **blue motion sensor** to the side of the table.



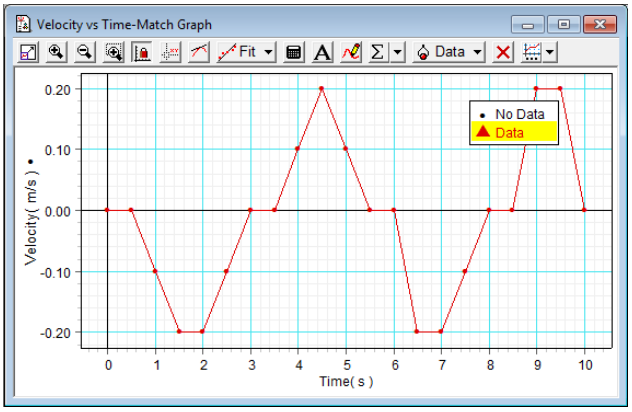
In the **Motion Graph Matching** Your instructor will pick out the position and velocity curves that you need to evaluate. When you run the graphs there will be a initial recording of the position for the first ten seconds. After it will start over again. This is done so that you have an idea where you should start. At the end of this section when you close the software a window will pop up. Make sure to click on **Discard**. **Also, unmount and unplug the blue motion sensor and remount and place the black motion sensor back in the original position.**

4.2 Additional assignment to be included in your final lab report

Analyze the graph below and explain what is happening with regards to position, velocity and acceleration. Use the graph to answer the following questions:

Intital will your direction be positive or negative? Maximum absolute value of speed you're able to obtain? Was it positive, negative, or both? Total time to run the motion?

Of the given velocity vs time graph. Make a very rough sketch of your position vs. time. The derivative of a position vs. time curve should roughly produce the given velocity vs. time graph. (Assume the corners of the velocity vs. time curve are rounded. Your position vs. time curve is the integral of the velocity vs. time curve.)



5 Please put back the lab equipment as you found it! Thank you!