Lab M2: Motion Graphing with the Motion Detector and Computer
(Windows 2000 Professional version)

Aug 21, 2003

Equipment / Materials per station:

ULI interface attached to computer
Motion Detector with cable to connect to ULI interface
Logger Pro software
Graphical Analysis Software
Meterstick
Clear hallway area
seniors partnered with juniors

A1) *Setting up (some of this may already have been done, but just in case…)*

Hardware set-up:

Be sure the ULI interface is plugged into both the computer and an electric outlet. Be sure the motion detector is plugged into Digital/Sonic Port 1 of the ULI.

Software set-up

1. From the START menu, select PROGRAMS and then the VERNIER SOFTWARE folder. Open the LOGGER PRO 3.1 software.
2. Close the Tip of the Day popup box if it appears. If a Setup Interface box appears, click Scan, then OK. You do NOT want a gray box to appear that says "Device Not Found" or something to that effect. If you do get such a message, you will have to troubleshoot a bit to find out what's wrong; some possibilities include: ac adaptor not plugged in, cable connection between motion detector and interface not secure, etc.. Feel free to call for help if your troubleshooting does not isolate and correct the problem. Hint: A green light on the Motion Detector should be a good sign that it's working.
3. Go to FILE on the menu bar and select OPEN. Browse until you find the folder titled EXPERIMENTS. Inside this folder, open the folder named PROBES AND SENSORS, then the folder called MOTION DETECTOR. Now open the file entitled MOTION DETECTOR. You might see one or more graphs position-vs-time or velocity-vs-time on the screen—(this display is easily modified by the steps outlined in the instruction box below.)
4. Under Experiment, select Show Sensors (LabPro). Check that the following settings are present: DIG/SONIC1 should be highlighted; Motion Detector should be the sensor. If any of these settings are incorrect, call the instructor over, otherwise click Close. If a message pops up in regards to an inappropriate default calibration folder, call the instructor over.
5. Under Experiments, choose Data Collection. Change the Length of the experiment to 5 seconds and the Sampling Rate to 10 samples/second. Click Done.

General instructions for choosing the on-screen graphs/meters displayed using the motion detector (refer to this part when you need to change the graphs displayed)

1) Decide which graphs to display. In general, you should always display the Position graph, and you may add the Velocity (and Acceleration graphs) ***ONLY IF*** you have predicted them first in your lab book.
2) ***To remove graphs or meters***, right-click on the graph or meter you want to remove, then select Delete.
3) ***To add graphs or meters***, go to Insert and choose Graph (or Meter). Left-click on the y-axis of the new graph and choose your dependent variable (position, velocity or acceleration). A left click on a new meter lets you change it also.
4) To modify a graph that already exists, you must put the graph in front of any other graphs that overlap with it. To do that, right-click on a graph and choose Move to Front or Move to Back as needed.
5) Once you have created all the graphs you want to see, arrange your graphs so that they are all aligned vertically; resize them so they are all about the same size. The position graph should always be on top, followed by the velocity graph below.

A2) ***Shutting down and putting away equipment (please remember to do this at the end of the period)***

1) IMPORTANT: Remove the Motion Detector ***cable*** from the Lab Pro box, being careful to press on the plastic tab of the connector while pulling out the cable. The green light on the Motion Detector should then be off.
2) Put away any carts or inclined planes that you brought out so that the hallway is clear for traffic.

B) Finding the Range of the Motion Detector ***(please limit yourself to 8 minutes max in this part)***

1) Right-click on any displayed graphs, and choose Delete. Under Insert, select Meter.
2) Right-click on the meter window you just created. Select Meter Options. Change the Column to Position. Click OK.
3) Click the button labeled Collect. The Position Meter will show the position (in meters) of the nearest solid object, relative to the sonic ranger.
4) Your job in this part is to experimentally determine the approximate minimum position and the maximum position that the sonic ranger measures correctly (allow for several centimeters of uncertainty). You'll need a meter stick to know the "accurate" positions. Record the results for the workable range of your Motion Detector on your lab report sheet. Check with the instructor to see if your answers are reasonable. In the remainder of the lab, REMEMBER THE LESSON OF THIS PART !

In the exercises that follow, be sure to clearly sketch your prediction FIRST. Then collect data and draw in the actual results on the same axes as your prediction. Use different colors for predictions and actual results. Put word labels, units, and numbers on your axes.

C) Position, time, & velocity for a stationary object

1) Close the Digital-Live meter window (by right clicking on it and choosing delete). There may now be one or more graph windows showing—if not, create one. You want only the position graph to be visible, so if the velocity and acceleration graphs are showing, remove them (see instructions at the bottom of previous page.) Double click on the numbers on the vertical ("distance") scale and select "Autoscale from 0", then OK. You can always readjust the scaling as needed.)

2) While standing still, aim the sonic ranger at a wall. Before asking the software to produce a graph of the wall's position vs. time, predict what you think that graph will look like (don't worry much about putting exact numbers on your axes; you only need to predict the *shape* and the rough position values(s) of the graph). Make a sketch of your predicted position graph in your lab report on the upper provided axes; reserve the bottom graph for the velocity vs time graph that will come later. Label your axes: position and time.

3) Once you've predicted the shape of the graph, aim the sonic ranger at the wall and click on the Collect button to get the software to plot the graph. To set the proper scaling, click on the vertical axis, then select Manual Scaling (under Axis Options) and type in 0 for the Minimum and 3 meters for the Maximum. Does your prediction agree with the plot? If so, note that in your lab report. Otherwise show the actual position-vs-time shape (on the same graph); distinguish "predicted" and "actual" with labels.

4) You probably have some familiarity with the term velocity. What is the velocity of the wall (with respect to the sonic ranger) for the situation described in situation #2 above? What would the velocity-vs.-time graph for the wall look like? Make a prediction and sketch it in your lab book right below the position-

vs.- time graph. Remember to label your axes with words.

5) We hope that you answered zero (or some equivalent) to the question about the velocity of the wall. Now go back to the computer and check your prediction. The instructions for adding a graph are on the 1st page. You should still keep the "distance" graph but add the velocity graph below the distance one.

6) Now look back at the position-vs.-time graph for the wall that you predicted and that the computer plotted. Is there anything ***zero*** about the position-vs.-time graph? Talk it over with your partner.

7) We trust that your answer to the previous question, without looking ahead, was something like "the slope of the line or graph is zero." Now, is it a coincidence that both the velocity and the slope of the line are zero? In your lab report, write a general definition of the slope of a line. Do not use the symbols x and/or y in your answer, but you may use words like horizontal, vertical, change in, rise, and/or run.

8) If we now apply your definition of slope specifically to a position-vs.-time graph, we see that the slope of the graph is the *change in position* divided by the *change in time*. And this is exactly the definition of velocity.

D) Position, time, & velocity for a slow steady walk away

9) Now let's try something that moves. One person will walk away from the sonic ranger at a fairly slow but constant rate. But before you ask the computer to record data, sketch a prediction of the position-vs.-time graph for the slow-walking person. Again, label the axes (but do not worry about numbers other than the origin on your graph). Compare your prediction to your partner's.{hint: look ahead to part E to plan how to scale your graphs for D and E since they will be on the same set of axes.}

10) Now collect data -- but first, remember to turn the velocity-vs.-time graph off (you haven't predicted it yet, right?) The person who walks should begin at a distance from the sonic ranger that is roughly equal to the minimum distance for which the ranger works; you might also want to set the maximum distance to 3 meters. Record the computer-generated graph. Double-clicking on the face of the graph allows you to select various options for that graph, including all options you get by double-clicking on the axes or the scales. ***NOTE:*** If you occasionally get spikes (exceptionally high or low points) on the graph, this is due to the failure of the ranger to detect your reflected signal. It sometimes helps to hold a reflector in front of the ranger as you are walking. This could be a book or other hard, flat surface.

11) Did your prediction match reality? Check with the instructor if you're not sure. Determine the slope of the position vs. time graph by reading two ordered pairs (time, position) of coordinates near opposite ends of your line and doing the calculation. Avoid using points that seem to be noticeably off from the general trend. To obtain coordinates, under Analyze, select Examine; then drag the mouse around your graph. Label the points used on your graph. Show all your work in the provided space on the report sheet, and ***include units*** (m, s, m/s) ***every time*** you write a position, time, or velocity number.

12) Once you have calculated the slope of your position-vs-time graph using two ordered pairs, let's try something different: under Analyze, select Tangent. Then drag the mouse along your position-vs-time line. How do the Tangent values compare to the slope you calculated (take 5 or 6 tangents and average)? How *should* they compare to your calculated slope value?

13) Now for a new prediction. What would the velocity-vs.-time graph look like for the walk done above? Sketch your prediction immediately below the position graph (don't worry about numbers on axes). (Hint: Was the velocity of the walker constant? How could you tell from the position-vs.-time graph?)

14) After you have sketched your velocity-vs.-time graph prediction on your report sheet, go back to the computer and add the velocity-vs.-time graph (no, you don't have to retake the actual motion data).

Leave the position-vs.-time graph on. You might also set the minimum velocity equal to zero and the maximum velocity equal to 2 m/s to better scale the graph. Was your velocity-vs.-time graph prediction correct?

15) Pick a time interval of interest (that lasts at least half a second) in the relevant part of the motion graphs. Record the data pairs (time & position and time & velocity) for each graph. Be sure to label these points completely on the graphs. Now determine the area under the velocity-vs-time graph for this interval. This is done by first selecting the part of the graph to analyze by doing a click and drag. Then choose INTEGRAL under ANALYZE. How does this area compare to the change in position of the object during this selected time interval?

E) Position, time, & velocity for a faster steady walk away

16) The other partner will now try a faster walk away from the sonic ranger. Before this happens, however, make a prediction of the position-vs.-time graph ***on the same axes*** as your previous prediction for the slow walk. Label the first prediction slow and the second one fast. Also predict the velocity-vs.-time graph (don't worry about numbers here) for the fast walk and record it on the same velocity graph for the slow walk. Label both lines – faster, slower. Use different color pens or pencils.

17) After predicting both position-vs.-time and velocity-vs.-time graphs for the fast walk, collect data for that walk, remembering to start at about the minimum working distance of the sonic ranger. Did your actual graph match predictions?

18) Now use the EXAMINE option under the DATA menu. Choose two points on the relevant part of the position-vs-time graph to calculate the slope of that graph. Show the work on your report sheet. Be sure to include all steps and units.

19) This time, use the TANGENT option under the DATA menu. Find several tangents to the relevant part of the position-vs-time graph. Determine the average tangent. Don't forget units! How should this tangent compare to the slope calculation you just did with two points? Why?

20) Summarize what you have learned so far about how velocity information shows up on an object's position-vs.-time graph. Can velocity be negative? How?

21) Pick a time interval of interest (that lasts at least half a second) in the relevant part of the motion graphs. Record the data pairs (time & position and time & velocity) for each graph. Be sure to label these completely on the graphs. Now determine the area under the velocity-vs-time graph for this interval. Show your calculation. How does this area compare to the change in position of the object during this interval. Is it ok for a graphical area to be negative?

F) Position, time and velocity for a slow steady walk toward

24) Repeat part D except walk toward the sonic ranger.

G) Position, time and velocity for a faster steady walk toward

25) Repeat part E except walk toward the sonic ranger.

H) Slowing Down

26) Use a dynamics cart (cart loaded with a concrete-filled soda can to make it more stable) for this activity. Set the ranger on the floor, aimed at the cardboard reflector taped to the back of the cart. Change the software settings to give you ***only*** a position vs. time graph; set the maximum position to 3 meters.

27) In this part you will give the cart a push away from the ranger with no obstacles in the way of the cart. Try it first without the sonic ranger recording data (just turn the ranger face down on the floor temporarily). Then predict the position-vs.- time graph for the cart as it rolls along the floor, AFTER you have finished pushing the cart. If the cart slows down as it moves, how is that seen on the graph? What would cause the cart to slow down? Did it actually slow down? Be sure your sketched graph REALLY conveys your understanding of its shape. Describe what happens to the slope of the graph as the cart slows down. Describe the shape of the graph in words. Collect data and record the actual position vs time graph of the cart.

28) Based on the cart's position vs. time graph, predict (in the space immediately below the position-vs-time graph) what the velocity vs. time graph of the same motion will look like. (Hint: As the slope of the position-vs.-time graph changes, how does the velocity-vs.-time graph change?) Be sure your sketched graph really conveys your understanding of its shape. Describe the shape of the graph in words.

29) Turn on the velocity vs. time graph and check your prediction from (22). Sketch the actual graph you obtain (if different from your predicted graph). Was your prediction correct?

30) When you compare the actual velocity-vs.-time graph to your prediction, you may find that the former has more irregularities than you might expect. This is due to the fact that the velocities are not measured directly by the ranger but instead are calculated by dividing the differences in position between successive data points by the corresponding time differences. Since the differences are quite small, substantial error is introduced into the calculated result. These errors show up as bumps and valleys in the graph. You should be looking for overall trends in the graph. Redo the data taking if it is too difficult to see a clear trend in your collected data. On your report, convey the trend of the graph not the "spikes" that might have occurred.

I) Abruptly Changing Direction

31)Next you'll look at a collision. If you push the cart so that it rolls quickly and then the plunger end strikes a wall, the cart will push back off and return. Try to make the cart move fast enough so that you do not see it slow down as in part H. Set up the ranger facing the wall and about 2 meters away. Put the cart about a half-meter from the ranger, ready to be pushed toward the wall. But wait! That's right, make your predictions of the position-vs.-time and velocity-vs.-time graphs. (If you don't think you can do both together, do the position one first, verify, and then predict the second.) You can, however, try the experiment without having the sonic ranger recording, if that will help you visualize the position and velocity graphs. Once you've predicted, push the cart and record results. Careful – don't knock the detector over !

32)When the cart reversed its motion at the wall, how did the position vs. time graph change? Be sure to be specific in discussing the slope of the line.

33)How did the velocity vs. time graph change? Again, be specific.

34)Something to note at this point is that changes of velocity are caused by the application of forces. When the moving cart slows down simply rolling along a level floor, that is due to frictional forces. When the cart changes direction, that is due to the push of the wall on the cart. (It may seem strange to think of a solid, immovable wall as exerting a push. Later we'll see that walls, floors, and other "immovable" objects can indeed exert such forces.)

35)Something else to note is that there are two ways that velocity can change. One way is when the object speeds up or slows down. The other is when the object changes direction. Remember, velocity is a VECTOR.

J) Speeding up

36)In this part, you'll look more closely at acceleration. Use the same cart as before, but allow it to roll down an inclined ramp. You'll find a variety of boards in the lab to serve as ramps. Start with an incline angle of just a few degrees. **Continue to make predictions before performing each of the experiments**.

37)Here, you'll start the cart at the top of the ramp. Position the sonic ranger aimed down the ramp so that the cart will move away from the ranger while rolling down the ramp. Obtain position-vs.-time and velocity-vs.-time graphs and record them only for the times while the cart is on the ramp – don't worry about data once the cart leaves the ramp. You may need to change scales if the maximum values are too small/large.

38)Describe in words each of the graphs you just obtained. Use words like constant, increasing, decreasing, slope, positive, negative, zero.

39)How do you think you could determine the rate at which the velocity of the cart is changing ? (Hint: Velocity is the rate at which position is changing. Think about how you found velocity from a position-vs.-time graph)

40)We hope that you realized that the slope of the line on the velocity-vs.-time graph is the rate of velocity change – a fancy word for this is acceleration. You can calculate a value for it by reading two (time, velocity) coordinate pairs from the graph and using the slope formula. Do that now beside the velocity graph, and be sure to carry units throughout the calculation. Note that the units of acceleration are m/s per s or m/s^2 for short. Be sure you use widely spaced values for the data while the cart was on the ramp (so that you get a good overall average value for the acceleration).

Do the "checkup" at the end of the report form. Write your conclusions concerning this lab. Ask yourself what important concepts were "discovered" by you, discussed, or reviewed.