LAB 01-3: Video Analysis of Uniform Motion

Objective

In this experiment, you will measure and graph the x-position of a rolling steel ball as a function of time. In addition, you will learn how to use video analysis software to measure position as a function of time for any object.

Pre-Lab: Introduction to Video Analysis

A video is basically a set of images taken at an interval of 1/30 s between frames. (However, high-speed video has a higher frame rate.) To measure an object's position, you need to:

1. define a coordinate system including an origin and x,y axes.
2. define a scale; in other words define a standard length, perhaps 1 m, in the video. For this, it helps to have an object of known length, such as a meterstick, in the video.

For example, consider the object in Fig. 1. To measure its x-position, draw a perpendicular line from the object to the x-axis. To measure its y-position, draw a perpendicular line from the object to the y-axis.

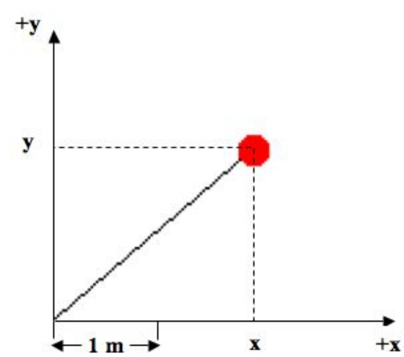

Figure 1: Position of an object depends on the origin and scale of the coordinate system.

Using the 1 m scale shown in the image, determine the distance of the object from the origin in Fig. 1

Video analysis software makes it easy to measure position coordinates (both x and y) and time for an object. After defining the scale and the coordinate system, you click on the object. The software shows a dot where you clicked and advances the video to the next frame. The software also measures time because it knows that the video is recorded at 30 frames per second. Thus, whenever you advance the video, time advances 1/30 s.

Suppose an object moves with uniform motion in the +x direction. Fig. 2 shows an object at intervals of 1/30 s between the first image on the left and the last image on the right.

Suppose that we define $t = 0$ to occur at the initial position of the object (the left image). In Fig. 2, label the time t for each subsequent position of the object.

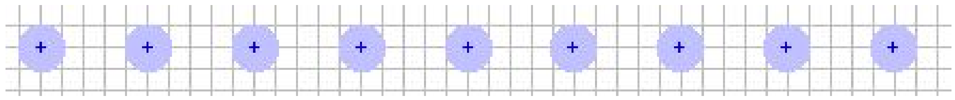

Figure 2: Position of an object at equal time intervals of 1/30 s.

Measure the x-position of the object from the first image to the last image. Define the origin $x = 0$ to be the position of the object at $t = 0$. Make a data table below showing x-position (x) and time (t) for the object.

By examining the x-coordinate of the object as a function of time, is the x-motion characterized by uniform motion or non-uniform motion (speeding up or slowing down, for example)? Give a reason for your answer.

Sketch a graph of x vs. t for the object. No numbers are needed.

If the object instead moves to the left and if the origin is defined to be the furthest image on the right, what would the graph look like?

Experiment–Uniform Motion of a Steel Ball Rolling on a Metal Track

1. Go to our course web site, click the link to `Videos`, and download the file `01-3-constant-velocity-slow.mov` and the file `01-3-constant-velocity-slow.mov` by right-clicking on the link and choosing **Save As...** to save it to your desktop.

2. Open the *Logger Pro* software on your computer.

3. Use **Insert→Movie...** to import your video.

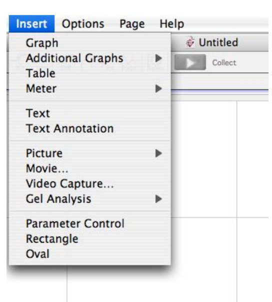

Figure 3: Insert movie menu

4. To expand the video, click once on the video, grab the corner of the video window, and expand.

5. At this point, it's nice to lay out the video, data table, and graph so that you can clearly see everything. Go to Page→Auto Arrange... to organize the screen, as shown in Fig. 4.

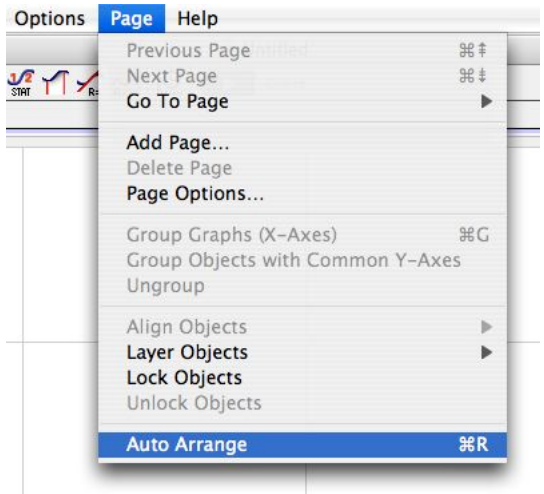

Figure 4: Auto arrange to clean up the panes in the window.

(You can always make the video larger or smaller and auto arrange the page in order to clearly see the data, graph, and video at the same time.)

6. Note the video controls at the bottom of the video pane, shown in Fig. 5. Go ahead and play the video, step it forward, backward, etc. in order to learn how the video controls work.

Figure 5: Video controls used to play and step the video

7. Navigate to the first frame after the ball has left the person's hand. This is the instant that you will begin making measurements of the position of the moving object.

8. You now need to define the origin of the coordinate system. Click the icon in the bottom right corner of the video pane (the icon with three red dots shown in Figure 6) in order to expand the sidebar used for video analysis.

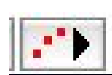

Figure 6: Icon used to expand the sidebar of the video pane

9. In the sidebar of the video pane, click the icon in Fig. 7 to show the coordinate system (you can hover the mouse over each icon to see what they do).

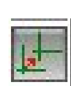

Figure 7: Icon used to set the coordinate system

10. Click and drag on the video to place the origin of the coordinate system at the location where you would like to define (0,0), as shown in Figure 8. For this video, you can place the origin at any point you choose, but it's typical for one to place the origin at the location of the object in the first frame being analyzed.

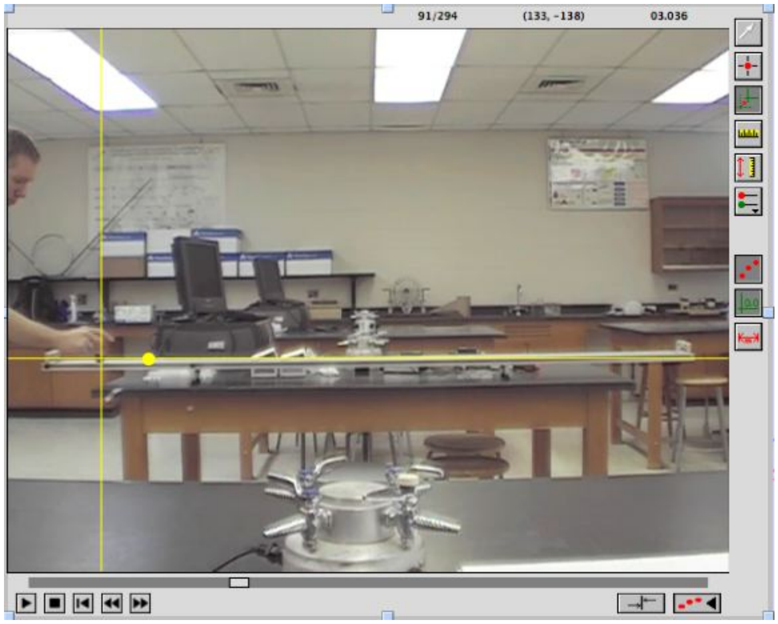

Figure 8: Click and drag to set the origin of the coordinate system

11. There is a solid, yellow dot on the x-axis. If you click and drag this dot, you can rotate the coordinate system. In this case, the video camera was not level; therefore, rotate the x-axis until it is parallel to the track.

12. Now, you must calibrate distances measured in the video. In the sidebar, click on the icon shown in Figure 9 to set the scale for the video.

Figure 9: Icon used to set the scale.

13. You are ready to add markers to the video to mark the position of the ball. First, let's not show the coordinate system and scale. It's too distracting. So, click each of the two icons in the lower right corner of the video pane, shown in Fig. 10. These icons are used to hide or show the coordinate system and scale.

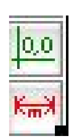

Figure 10: Use these icons to show or hide the coordinate system and scale.

14. To add markers, first click on the icon with the red dot and cross hairs, shown in Fig. 11. You will now be in an editing mode to add points.

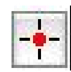

Figure 11: Icon toggle the editing mode for marking positions in the video.

15. In this case, we will mark the center of the ball. Click once on the center of the ball. You should notice that a marker appears at the position of the ball where you clicked and that the video advances one frame.

16. In this case, the ball does not move very far in 1/30 s; therefore, advance the video 5 frames, counting "1, 2, 3, 4, 5" each time you advance the video one frame. Again, click on the ball to mark its position.

17. Continue marking the position of the ball, advancing the video 5 frames between marks. Be sure to count so that you are consistent in how much you advance the video between marks. After marking the ball as it moves from the left end to the right end of the track, your video should look like the picture shown in Fig. 12.

Figure 12: Marks showing the ball's position for successive frames of video

18. Logger Pro will calculate data for t, x, and x-velocity, and y-velocity. In this situation, we are only interested in the x vs. t graph and the x-velocity vs. t graph.

Analysis

1. Click the graph to bring it to the front. Go to **Page→Auto Arrange** to automatically arrange the windows so that the video and data windows are out of the way.

2. By default, it will show both x vs. t and y vs. t on the same graph.

3. Let's change what is being plotted. First, click the label on the vertical axis. By default, both X and Y are shown. When you click this label, you will have a menu that you can select what is being plotted. Select X for now.

What function describes this graph of x vs. t? (i.e. linear, quadratic, square root, sinusoidal, etc.)

4. Go to **Analyze→Curve Fit**. In the resulting window, select the linear function, as shown in Figure 13. Click the Try Fit button and Click OK.

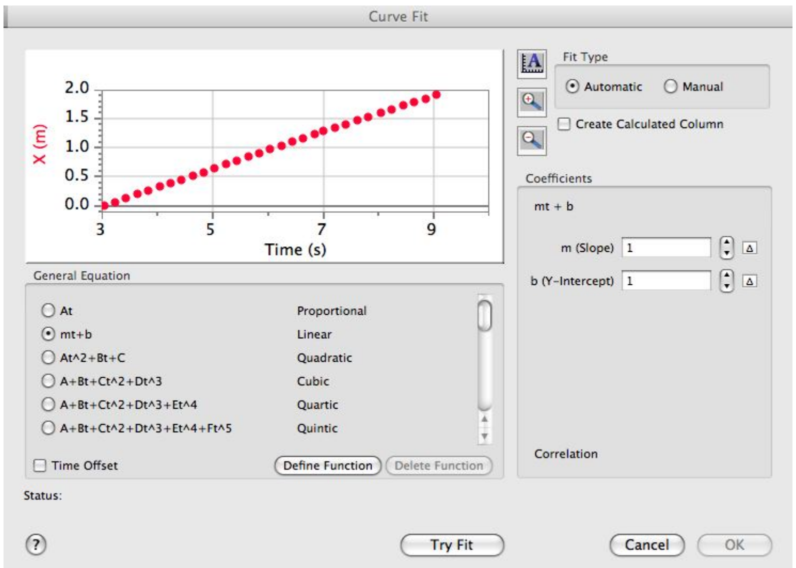

Figure 13: Select the linear fit.

Record the function and the values of the constants for your curve fit. Write the function for x(t), with the appropriate constants (also called fit parameters).

In general, what does the slope of the x vs t graph tell you? (Consider its units. Your answer should be a sentence, not a number.)

What do you expect the x-velocity vs. time graph to look like? Sketch your prediction below.

5. Change the vertical axis to X Velocity. Note that the data appears to be all over the place. That's because by default, the graph is "zoomed in" on the data. If you examine the numbers on the vertical axis, you'll notice that the data probably lies between 0.3 m/s and 0.33 m/s (though your data will vary from this). That's a very small variation in the velocity during the 8-second time interval that the ball is moving.

6. Go to `Analyze`→`Autoscale`→`Autoscale from 0`. The data appears to be along a horizontal line, though there is some scattering in the data due to uncertainty in the measurements. You might also notice that there is a slight downward trend in the data, showing that the x-velocity seems to slightly decrease as the ball rolls on the track. We will consider this to be negligible, since it's a small decrease.

7. Using your mouse, highlight the data by drawing a window around the data points as shown below.

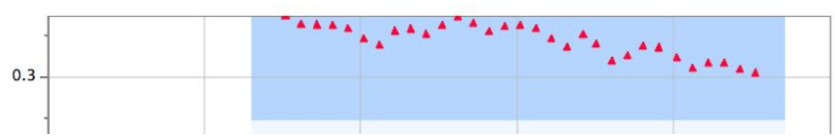

Figure 14: Highlight the x-velocity data.

8. In the toolbar, click on the `STAT` button, shown in Figure 15. Logger Pro will compute and display the average value of the data.

Figure 15: Statistical analysis icon in the toolbar.

Record the mean (average) value of v_x and the standard deviation. How does this compare to the slope of the x vs. t graph?