

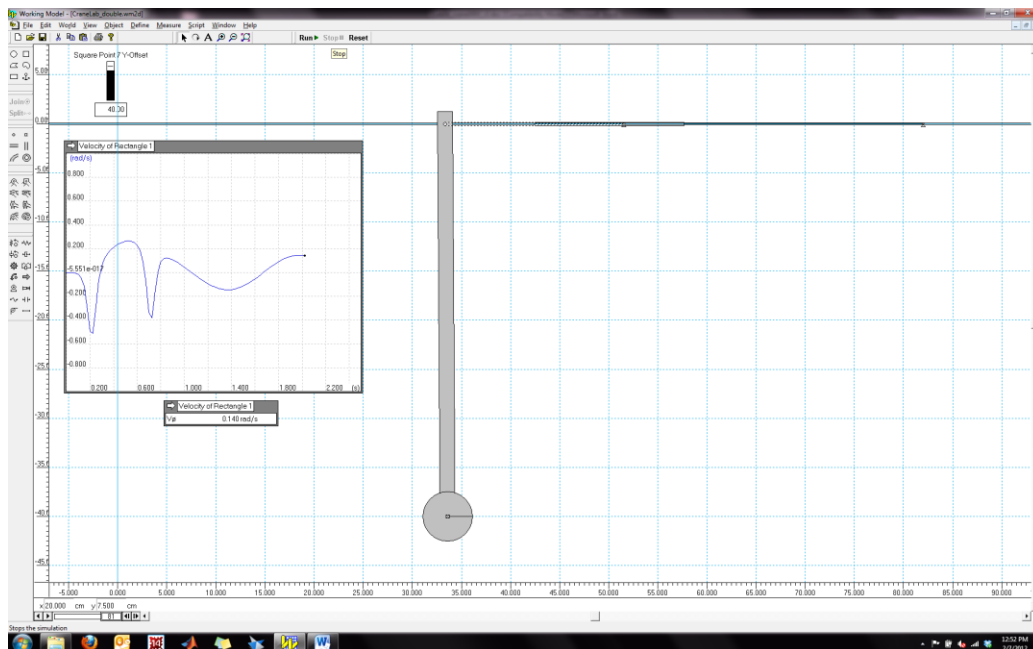
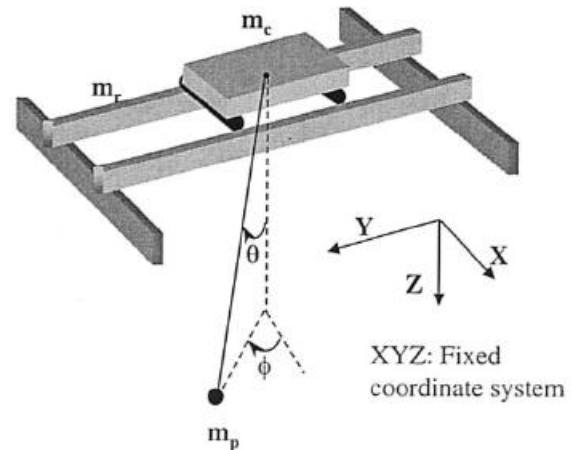
ES204 Lab 4 Working Model Simulation of Crane Movement

The purpose of this lab is to use Working Model to simulate and explore the behavior of an overhead crane moving a suspended payload.

In Lab 5, you will *experimentally* explore this same system. In a future homework assignment, you will predict the behavior of this system through *analytical* means using the material learned in class. If your simulation is well-built, the experiment is well-done, and the theoretical analysis is well-justified, all three methods will give similar results.

Precise payload positioning by an overhead crane (especially when performed by an operator using only visual feedback to position the payload) is difficult due to the fact that the payload can exhibit a pendulum-like swinging motion. In this lab, we will see that there are strategies for moving the payload that reduce the swinging motion that occurs after the crane has stopped moving. Our basis for comparison is the final angular velocity of the rod (that represents the crane's cable) after the crane has stopped moving.

When you are finished, your final Working Model should look like the following:




Overhead Crane Figure taken from: Y. Fang, W. E. Dixon, D. M. Dawson, and E. Zergeroglu, 'Nonlinear Coupling Control Laws for an Underactuated Overhead Crane System', *IEEE/ASME Transactions on Mechatronics*, Vol. 8, No. 3, September 2003



Build the Simulation

Be sure the units you are using are SI and radians (View/Numbers and Units). Set the mass units to grams and the length units to centimeters (View/Numbers and Units/more choices). It is often convenient to turn on a rulers, grid and axes (View/Workspace).

Create the pendulum geometry



1. Set view size window width to 100 cm. (View/View Size)
2. Create a rectangle  that is 43.2 cm tall by 1.5 cm wide (height = 43.2, width = 1.5 in the Geometry window) and has mass equal to 68.5g. This rectangle represents the pendulum bar.

Attach the pendulum to the horizontal crane track

3. Create a horizontal “slot element”  that will serve as the crane track.
4. Place a round point element  at the top of the rectangle (centered left-to-right). Select both the round point element and the slot element (shift-click) and then click Join.
5. In the experiment you will conduct for Lab 5, the pendulum bar is actually pinned in a slightly different location due to the size of the rotational sensor. To reflect this, modify the second formula for the y-location of the pin to be
$$\text{Body}[?].\text{height}/2.0-1.25$$

where you need to replace ? with the pendulum’s object number.

Create the adjustable weight

6. Create a circular object  of radius 2.5 cm to act as an adjustable weight. Place a square point  element in the center of the circle. Place another square point element in the middle of the bar and, while the square point element on the bar is highlighted, create a slider control to adjust the location of the circular weight along the pendulum bar (Define/New Control/Offset). Delete the x-offset control that appears. Double-click on the word “Y-offset” and set the minimum and maximum values to 0 and 40, respectively.
7. Select the square point element on the bar and change the y equation from “Input[?]” to
$$43.2/2-1.25 - \text{Input}[?]$$


When the offset is set to zero, the square point should be at the pin location of the bar.

8. Highlight the square point elements on the bar and on the circle (hold down the Shift key to select both objects) and then click on Join. The circular mass should now be attached to the bar. If you need to move the bar back into view, make sure it remains vertical (with angle $\phi = 0$ rad).
9. Set the adjustable mass weight to 88g and use the Y-offset control to move the mass away from the end of the bar.

Create a graph and meter to display the data

10. Create a graph to measure the angular velocity of the bar. Highlight the bar and select Measure/Velocity/Rotation Graph. Set the y1 range from -1 to 1 and the x range from 0 to 2.5. Be sure to deselect the “auto” checkboxes. Drag the corner of the graph to make it bigger—you want to be able to see the plots clearly.
11. Copy the graph and paste it in an empty section of your workspace. Click twice on the white arrow in the upper left of the meter to change the graph to a digital meter.

Add the actuators that will move the crane along the track for the “double move” strategy

12. Add the first horizontal actuator , anchored to a) the round point element at the top of the bar and b) at least 10 cm to the right of the bar, keeping the actuator horizontal. You may need to zoom in to be sure you select the round point element at the top of the bar as one end of the actuator. Open the actuator properties window and change the type to Acceleration, then type in the equation:

$$100.000*(-0.018952*43.5668^2*\exp(-43.5668*(\text{time}-0.2153))*(\exp(-43.5668*(\text{time}-0.2153))-1)/(1+\exp(-43.5668*(\text{time}-0.2153)))^3)$$

Change the ‘Active When’ to ‘time<0.5’.

13. Add the second horizontal actuator, just like the first (also anchored between the point element at the top of the bar and the right of the bar.) Change the actuator type to Acceleration and then type the second equation:

$$100.000*(-0.018952*43.5668^2*\exp(-43.5668*(\text{time}-0.7153))*(\exp(-43.5668*(\text{time}-0.7153))-1)/(1+\exp(-43.5668*(\text{time}-0.7153)))^3)$$

Notice that this is very similar to, but not identical to, the first actuator equation. Change the ‘Active When’ to ‘time > 0.5’.

Add Pause Control

14. Under World/Pause Control/New Condition type ‘time > 2’. Save this file with a name like “CraneLab_double”.

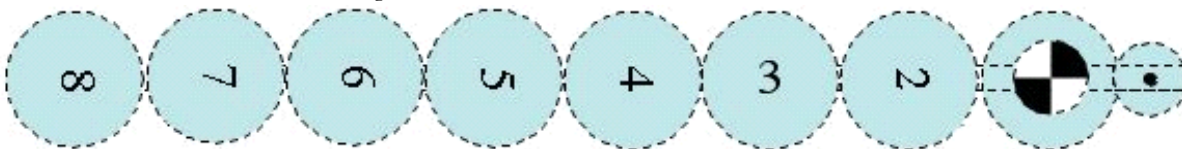
Make a new file for the “single move” strategy

15. For a single move strategy, save your Working Model file with a new filename (something like “CraneLab_single”). Delete the *second* actuator and double the magnitude of the first prescribed acceleration (change the coefficient 100*..... to 200*....) Change the ‘Active When’ to Always.

Explore the Problem

Using the Excel spreadsheet located on the course website as a guide, test the eight weight configurations described by:

$$L_{wcg} = d_s/2 + (n - 1/2)d_w, \quad n = 1, 2, \dots, 8$$



Where:

sensor diameter..... $d_s = 2.5$ cm
 moveable weight diameter..... $d_w = 5$ cm

Try both the single and double move strategies for each configuration. We are interested in the *residual* swing of the pendulum. To find the residual angular velocity, use the time slider at the bottom left of the screen to find to a peak or valley after the actuators stop (after 1 second) and then read the number from the meter. Record the absolute value in your Excel spreadsheet.

Finally use trial and error to find the *simulation* ideal mass location to reduce the residual angular velocity of the rod. You will compare this to the *experimental* and *theoretical* location. All three analysis methods are due Friday of 10th week.