

ME6404 – Fall 2016

Lab 6: Trajectory Following

Objectives:

1. Drive the tower crane through an obstacle course manually and with preprogrammed trajectories.
2. Win glory and prizes!!

Background:

In this lab, you will be competing against your classmates to achieve the fastest time through an obstacle course. Prizes will be awarded to the winners.

Certain crane payload configurations, like the one shown in Figure 1, can result in double-pendulum dynamics. The hook suspension length and the payload rigging lengths are L_1 and L_2 , respectively. The mass of the hook and payload are m_h and m_p , respectively.

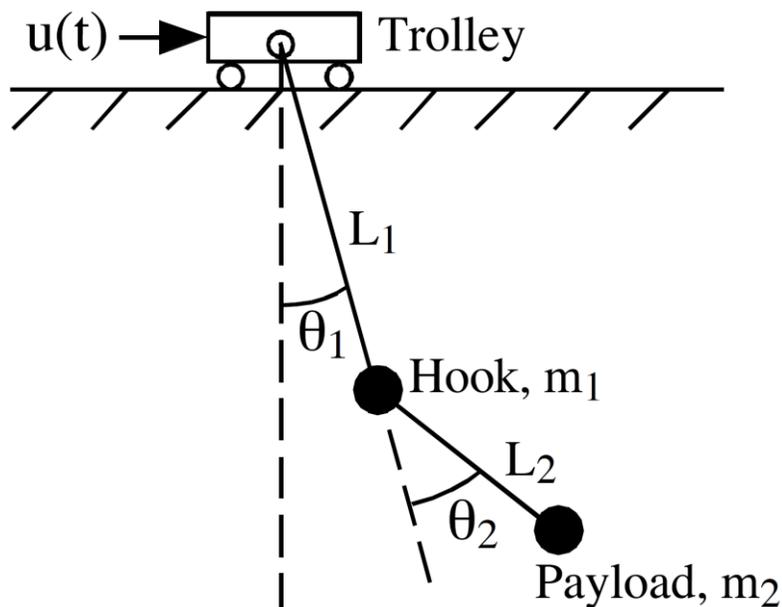


Figure 1: Double-pendulum crane

Lab Tasks:

Driving the tower crane through an obstacle course

The team must work together to complete these tasks on the tower crane

A picture of the obstacle course is shown in Figure 2. An overhead view of the obstacle course and an example trajectory are shown in Figure 3. Note that the actual obstacle course may not exactly like the one pictured but will be shown during the lab introduction.

1. The hook starts at the minimum height over the start position, indicated by the solid black circle in Figure 3. Timing begins when the crane starts moving.
2. Maneuver around or over the obstacles to pick up the payload at the position indicated by the red circle in Figure 3. The payload is a small water-filled bottle and a magnet. The magnet is attracted to the hook when they are close. The payload is placed at the center of the circular pickup zone.
3. Once the payload is picked up, maneuver to the finish, indicated by the black circle in Figure 3, and deposit the payload into the cup. Timing stops when the payload is fully inside the cup. The payload is allowed to hit the cup without penalty. However, all other surfaces (including the ground) are considered obstacles and incur penalties upon collisions with either the hook and/or payload.
4. Each collision is penalized **5 seconds**. Multiple collisions with the same obstacle incur multiple penalties, up to a maximum of **two penalties (10 seconds)** for each obstacle. Therefore, dragging the payload along the ground incurs a 10 second penalty.

The three categories of the contest are:

1. Manual operation using the GUI or joystick, without computerized command shaping.
2. Shaping-assisted manual operation using the GUI or joystick
3. Preprogrammed trajectory. Design a trajectory that is executed autonomously by the crane (no human interference is allowed). In both the manual and shaping-assisted manual categories. Completion times will be capped at 3 minutes.

Use the taped markers on the ground to return objects back to their original positions, if they are accidentally moved.

Table 2 contains information about the hook and payload.

Table 2 - Hook and Payload Information

Hook	0.210 kg
Magnet	0.005 kg
Bottle (payload)	0.7 kg
Rigging length (string between magnet and bottle)	0.71 m

If the suspension cable unwinds, then use the following pictures to rewind the cable. Note that the cable may also wind from the pulley inside the hook.

1. It is essential that the cable follows the track. Make sure that it has tension at all times. See Figure 4 for more information. The zip ties put pressure on the wire holding it to the guide wheels.
2. Figure 5 shows an untidy cable wound around a reel. Please make sure to keep the winding very neat and tidy. This keeps the wire from coming off. Also notice there is tape on the edges of the reel. This is to keep the wire in the winding zone. If the tape comes off please put it back on.



Figure 4: Cable with trolley

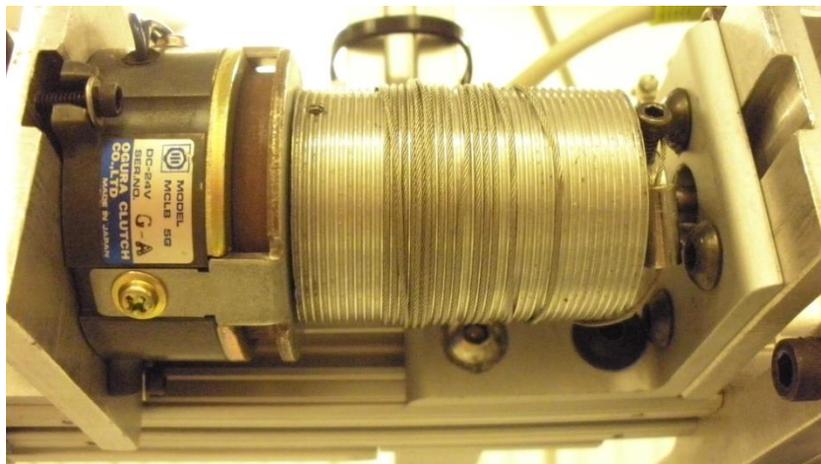


Figure 5: Wound cable reel

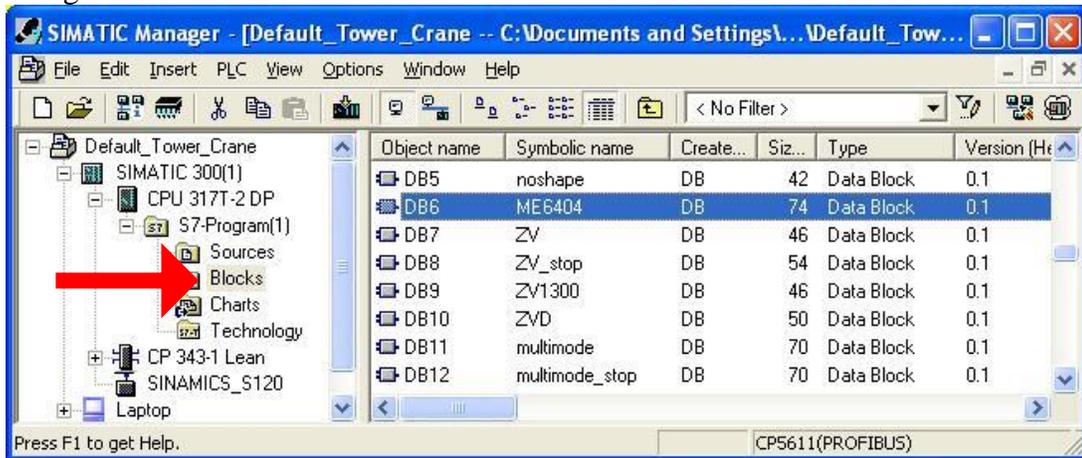
- Prizes are awarded to the winning group of each category
- The contest will be 2-3pm ET on Friday, October 28.

Lab Procedure:

1. Sign up for sessions on the Google calendar. (You are limited to blocks of 2 hours. You must leave a gap of at least 2 hours between any 2 of your reservations.)
2. Double click on the “Default Tower Crane GUI” link on the desktop.
3. Select **Remote User** from the operating mode. Click **Activate Mode**.

Entering input shapers

4. Open “SIMATIC manager” from the desktop. The “Tower Crane Nov 2011” project should be open. If not, use File>Open>Browse... and browse to file path “D:\Tower Crane GUI and PLC program 2016\Tower Crane Nov 2011.”
5. Navigate to the **DB6 ME6404** data block as shown and double click.



6. Go to **View>Data View** and you should see the following window. Modify the impulse times and amplitudes (you can specify up to **20** impulses) by changing the “**tap_times**” and “**tap_vals**” under the “**Actual Value**” column.

The screenshot shows the Data View window for data block DB6 ME6404. The table below shows the data structure:

Address	Name	Type	Initial value	Actual value	Comment
0.0	num_of_taps	INT	20	20	number of taps
2.0	tap_times[0]	INT	0	0	tap times in milliseconds
4.0	tap_times[1]	INT	0	1168	
6.0	tap_times[2]	INT	0	0	
8.0	tap_times[3]	INT	0	0	
10.0	tap_times[4]	INT	0	0	
12.0	tap_times[5]	INT	0	0	
14.0	tap_times[6]	INT	0	0	
16.0	tap_times[7]	INT	0	0	
18.0	tap_times[8]	INT	0	0	
20.0	tap_times[9]	INT	0	0	
22.0	tap_times[10]	INT	0	0	
24.0	tap_times[11]	INT	0	0	
26.0	tap_times[12]	INT	0	0	
28.0	tap_times[13]	INT	0	0	
30.0	tap_times[14]	INT	0	0	
32.0	tap_times[15]	INT	0	0	
34.0	tap_times[16]	INT	0	0	
36.0	tap_times[17]	INT	0	0	
38.0	tap_times[18]	INT	0	0	
40.0	tap_times[19]	INT	0	0	
42.0	tap_vals[0]	INT	100	50	tap vals in percent
44.0	tap_vals[1]	INT	0	50	

7. Do not modify “**num_of_taps**”. If you choose to use a shaper with less number impulses than the maximum number, then set the “**tap_vals**” of all unused impulses to zero.
8. Click the “**Download**” button shown by the red arrow to download the values to the PLC. The **ME6404** shaper is now set to your design.

Preprogrammed trajectory

9. Preprogrammed trajectories are implemented on the tower crane by using three text files (one for each axis: slew, radial, and hoist) with comma separated values (saved with .csv extensions).
 - Templates of these files will be on the website.
 - The header section of each file must remain unchanged. You can make the changes in Excel, but **it must be kept in its original format**. The following method will work (You can, however, use any method you prefer):
 - a. Open files in Excel
 - b. Modify values
 - c. Save; select “Yes” to keep file in the same format
 - d. Close file; but do not save changes
 - Each file contains velocity values representing **the percentage of the maximum velocity** for the given axis for each 40ms sample in time.
 - Information about the uploaded files is shown in Table 3.
 - The tower crane motion information is shown in Table 4.
 - These values are only approximate. You will need to experimentally determine other information (such as hoist velocity)

Table 3 - Trajectory Upload File Information

Axis	Filename	Convention
Slew	Upload_sl.csv	+ = counter clockwise
Trolley Radial	Upload_tr.csv	+ = out
Hoist	Upload_hk.csv	+ = up

Table 4 - Tower Crane Motion Information

Parameter	Min	Max	Units
Cable length	0.45	1.70	m
Slew velocity	-0.35	0.35	rad/s
Slew Acceleration	-0.7	0.7	rad/s ²
Radial Velocity	-0.14	0.14	m/s
Radial Acceleration	-1.20	1.20	m/s ²

10. Upload the files to the laptop - D:\upload_tr.csv, D:\upload_sl.csv, and D:\upload_hk.csv.
11. In the GUI, press **Stop**.
12. Press the **Upload** button to load your trajectory files from D:\ on the laptop to the PLC.
13. Press **Start**. Then press **Play** to execute your trajectory. Note the three files on D:\ must not be opened by other programs.

14. Use **Record** to record data. You can record about 80 seconds of data at 40 ms sampling rate. The positions and velocities of the trolley in the slewing and radial directions, and the hook deflection in the radial and tangential directions will be recorded.
15. Press **Download** to send the recorded data to an Email address.

Lab Report (one per team):

Present your work in **less than 2 pages of text (put all the figures at the end)**.

Begin with an introduction that briefly describes the goals of the lab. Then, include and explain the results from the lab.

- Include an analysis of the dynamics of the hook and payload that the crane will experience during its movement through the obstacle course.
- Justify the design of your shaper.
- Justify the design of your trajectory.
- Contest results.

The report is due Saturday, October 29 by noon. You should have it completed, except for the discussion of the contest results by the lab on Friday, October 28.