ME6404 – Fall 2017
Lab 5 – Trajectory Following

OBJECTIVES

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

BACKGROUND

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

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.

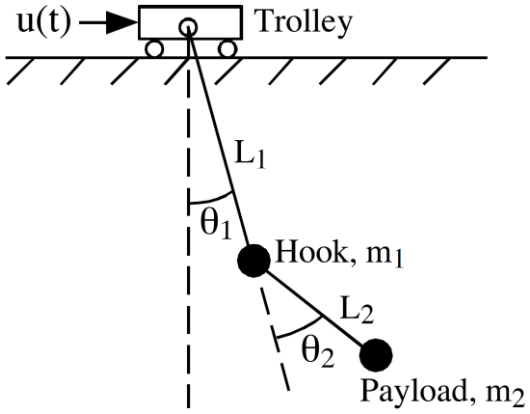


Figure 1: Double-Pendulum Crane Model.

LAB TASKS

Driving Tower Crane Through Workspace

A contest shall be held wherein participating teams attempt to complete a payload manipulation task as quickly as possible. The mini-tower crane will be used for the contest. There shall be three different types of manipulation tasks. These are:

1. Manual Operation Without Input Shaping.
    a. Local – Student drives crane while standing next to it using GUI or Pendant.
    b. Remote – Student drives crane from another room.

2. Manual Operation With Input Shaping. The same shaper must be used for all trials.
    a. Local
    b. Remote

3. Pre-Programmed Trajectory. Design a trajectory that is executed autonomously by the crane (no human interference allowed).

A picture of an example obstacle course is shown in Figure 2. An overhead view of the obstacle course and a sample trajectory are shown in Figure 3.

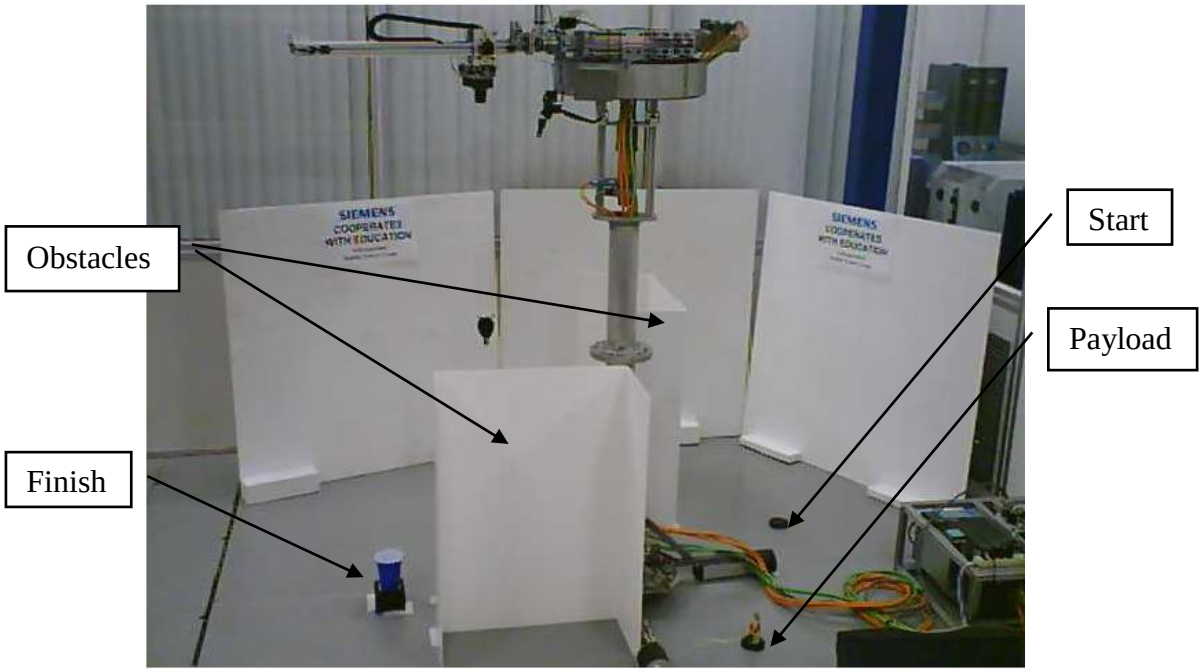


Figure 2: Obstacle course for the tower crane

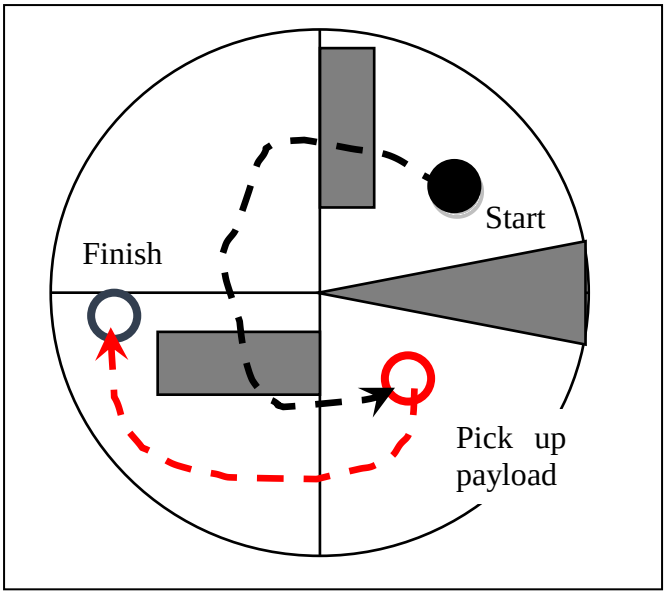


Figure 3: Obstacle course overhead view

Manipulation Task & Scoring Specifications

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.
5. In both the manual and shaper-assisted manual categories, the completion times for local and remote operation are combined to determine the winner of the category. Completion times will be capped at 3 minutes.
6. Hook and payload information are summarized in the following table.

Hook	0.210 kg
Magnet	0.005 kg
Bottle (payload)	0.070 kg
Rigging length (string between magnet and bottle)	0.70 m

Instructions for Winding the Cable

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.

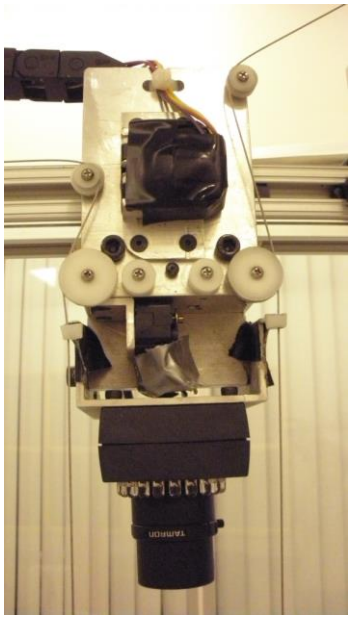


Figure 4: Cable with Trolley.

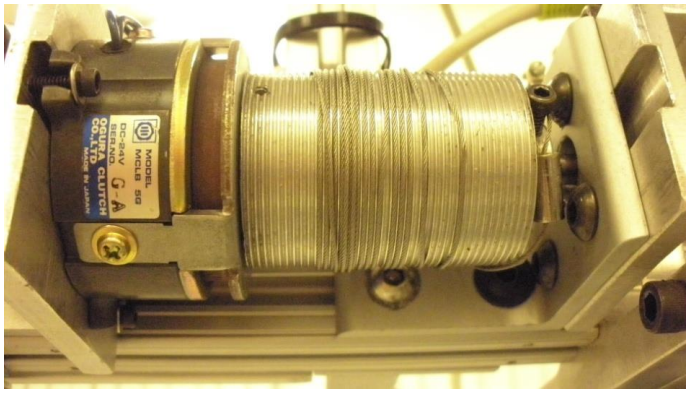


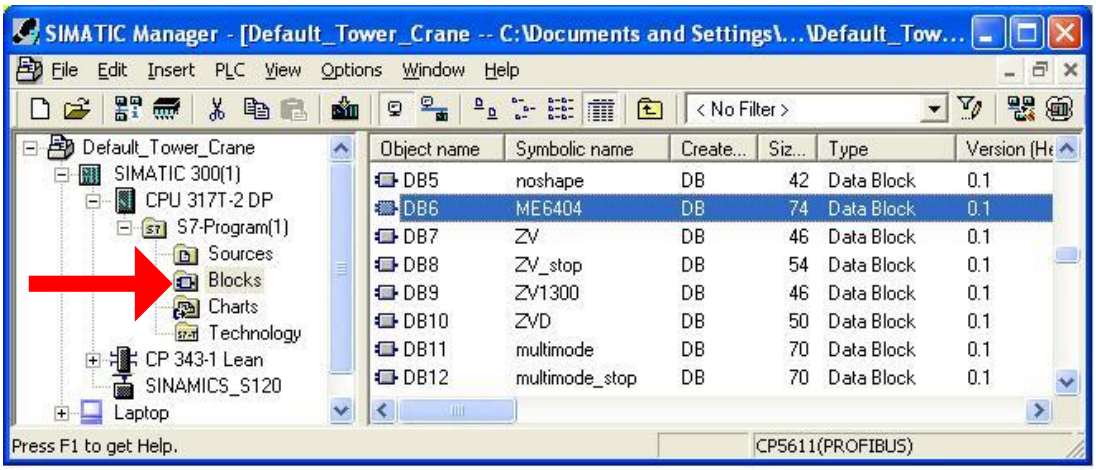
Figure 5: Wound Cable Reel.

LAB PROCEDURE

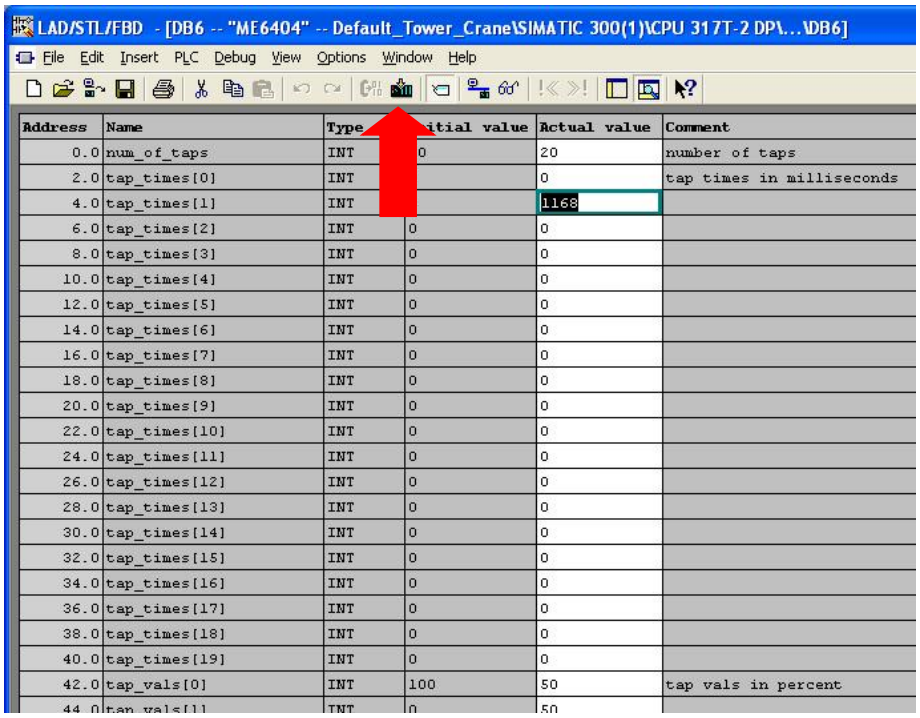
1. Sign up for sessions on the bridge crane Google calendar. You are limited to blocks of 1.5 hours. You must leave a gap of at least 1.5 hours between any 2 consecutive reservations.
2. Remote operation: Google Chrome Remote Desktop Instructions for Tower Crane.pdf.
3. Web cam: http://singhose.marc.gatech.edu/Tower_Crane_Webcam/Tower_Crane.html
   Login: user, Password: password
4. Double click on the "Default Tower Crane GUI" link on the desktop.
5. Select Remote User from the operating mode. Click Activate Mode.

Entering Input Shapers

1. Open "**SIMATIC manager**" from the desktop. The "Default Tower Crane" project should be open. If not, use **File>Open>Browse**... The project you should be using is in the "Default Tower Crane" folder located on the desktop.
2. Navigate to **the DB6 ME6404** data block as shown and double click.



3. 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.



Address	Name	Type	itial value	Actual value	Comment
0.0	num_of_taps	INT	0	20	number of taps
2.0	tap_times[0]	INT		0	tap times in milliseconds
4.0	tap_times[1]	INT		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	

4. 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.
5. 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

1. 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 supplied.
    - The header section of each file must remain unchanged. You can make the changes in Excel, but **it must be kept in its original forma**t. The following method will work:

        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 2.
    - The tower crane motion information is shown in Table 3.
    - These values are only approximate. You will need to experimentally determine other information (such as hoist velocity)

Table 2 - Trajectory Upload File Information

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

Table 3 - 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

2. Upload the files to the laptop - D:\upload_tr.csv, D:\upload_sl.csv, and D:\upload_hk.csv.
3. In the GUI, press **Stop**.
4. Press the **Upload** button to load your trajectory files from D:\ on the laptop to the PLC.
5. Press **Start**. Then press **Play** to execute your trajectory. Note the three files on D:\ must not be opened by other programs.
6. 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.
7. Press **Download** to send the recorded data to an Email address.

CONTEST

- The contest will be held during lab hours from 3 – 4 pm on Friday October 27, 2017.
- Prizes are awarded to the winning groups of each category.

LAB WRITEUP

Present your work in less than 2 pages of text. Your report should include the following:

- Analysis of the system dynamics that experienced by the crane during movement through the obstacle course.
- Justify the design of your Input Shaper.
- Justify the design of your Trajectory.
- Contest Results.
- The lab writeup will be due on the Monday following the contest at the beginning of lecture.