CHE 573- Signal Processing for Process Engineers
Assignment 5
Temporal and Spectral Analysis of Process Data plus Smart Alarm Monitoring

Due date: 4 April 2012 on or before 4 PM.

Objective:

1. Filter design and smoothing of real sensor data in Matlab. Remember the first step in successful analysis of process data is to carefully validate the sensors and the data that comes from these sensors. You cannot and should not proceed with modeling and other exercises unless you have first verified that the downloaded data is indeed credible.
2. To understand the significance of spectral and correlation analysis and to carry out simultaneous correlation analysis of process data in the temporal and spectral domains.

For the purpose of this assignment please download the following files from the 'Matlab-Functions' folder on the Elearning page for CHE 573:
'pump_data.txt,' 'psp.m', 'entech.mat', and 'DVAtool'

1. A heavy duty pump is used to pump sea water to an oil processing facility. A number of variables are measured in this pump, including the output flow rate and the head pressure, to monitor the performance of the pump. Flow rate (gal/min) and head pressure (psi) variables are measured every minute. Measurements for a period of about 30 hours are given in the file "pump_data.txt".

    a) Plot flow rate and head pressure data versus time. Can you visually detect any abnormality in the data?
    b) Plot the pump curve (head pressure versus flow rate). Can you now visually detect any abnormality in the curve?
    c) Fit a second order polynomial to the pump curve (use only the first 1000 data points for curve fitting). We use this second order polynomial as a model of the pump to predict the head pressure. (Hint: Use the function 'polyfit' in Matlab to do this).
    d) Plot the actual and predicted pump curve on the same axis. Comment on the plots.
    e) Calculate the prediction error (actual head pressure minus predicted head pressure) and plot it versus time. Can you visually detect any abnormality in the prediction error? What is the approximate time of abnormality? From now on we refer to this abnormality as a *fault*.
    f) Observe the individual time trends of flow rate and head pressure plotted in part (a) again. At the time of fault occurrence, can you notice any sign of abnormality in time trends?
    g) Calculate the mean (μ) and the variance (σ^2) of prediction error (use only the first 1000 data points for calculations). Compare the prediction error with check limits set at $\mu \pm 2\sigma$. How many false alarms do you get (an alarm is triggered when the

prediction error exceeds the limits)? How many alarms are missed (when a data point in the *fault* segment falls within the check limits, an alarm is missed)?

h) Apply a moving average filter with window size 5 to the prediction error. Plot the filtered error versus time.

i) Plot the histograms of unfiltered and filtered error. You can use the `hist` command in Matlab. Make sure to select an appropriate number of bins. Comment on the plots.

j) On the histogram of filtered data, locate the point on the horizontal axes that almost separates the two bell-shaped distributions. Set the upper check limit to the corresponding value. No lower check limit is required. Compare the filtered error with the new check limits. How many false alarms do you get? How many alarms are missed? Comment on the effect of this filter on false alarm rate and detection delay.

2. For this second question you are required to download the 'DVAtool' and 'entech' files from the Elearning page for CHE 573. Unzip the DVAtool files in a separate folder. In the Matlab command window, load 'entech' and then type DVAtool at the Matlab prompt. This will open the DVAtool GUI.

   The entech data comes from a simulated process shown in Figure 1. It consists of a pulp manufacturing process, where the hardwood and softwood pulps are mixed to give a stream of desired composition. The data set is comprised of 1934 samples from 12 process measurements (tags), each of which was associated with 12 control loops. The objective of this analysis is to detect oscillations in the loops and isolate those loops with common oscillations.

   Load the entech variable from the Matlab workspace into DVAtool and do the following:

   a) Obtain a High density plot of all 12 variables. This is a simultaneous display of the time trends and the corresponding spectra of all the 12 measured variables. This is also known as the High Density Plot. (The spectra in the HDP are normalized such that the total power in each variable is unity.)

   b) Comment on your observations and compare the temporal and spectral correlation plots and outline the advantages and disadvantages of these two plots.

   c) By looking at the time trends alone are you able to identify the sinusoidal signals embedded in these 12 variables?

   d) Separately obtain the correlation coefficient matrices (in the temporal and spectral) domains for this data and check if the coefficients that you obtain agree with the colour coded correlation plots.

e) The basic objective in this problem is to identify all variables with common oscillations, and extract the basic shapes for each of these groups. By examining the process flowsheet (Figure 1) comment on the likely root case variable(s) that are the source of these oscillations.

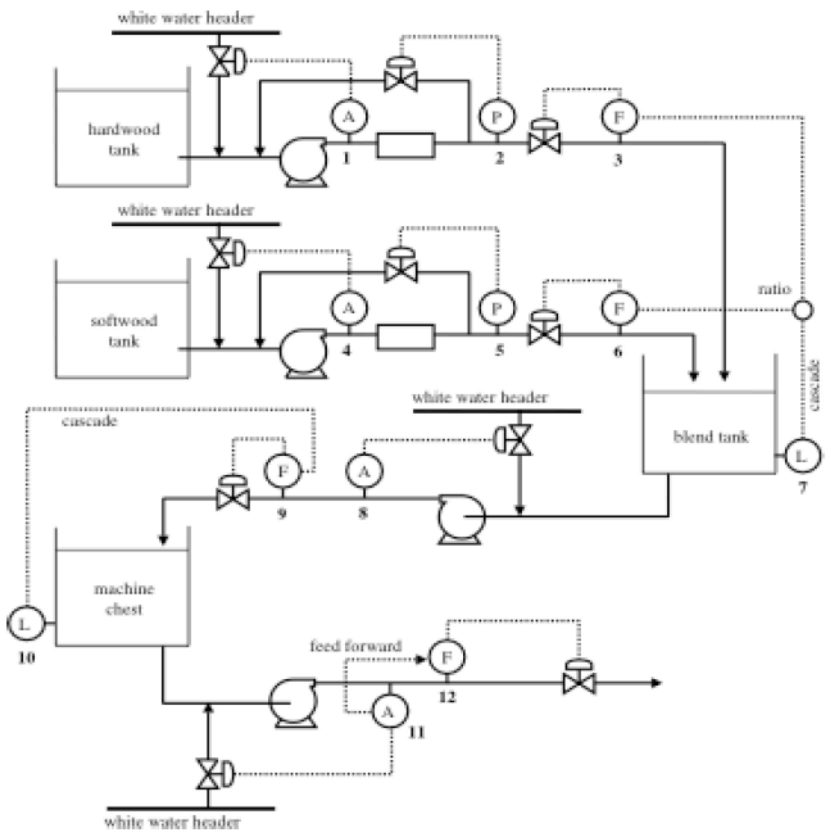

Figure 1: Schematic of the simulated Entech process