# Homework Assignment #3 for

## EE392m - Control Engineering in Industry, Spring 2005

### 1. Model Identification

This problem is from the Matlab Identification Toolbox demo `iddemo`. To see the problem description run `iddemo` and select

        13) Case Studies

from the menu (Note that Case Studies are #12 in Matlab Rel 11). Then select

        1) A glass tube manufacturing process.

You will need all this only for an explanation of the problem and as baseline against which to compare your solution. The task is to do identification in a different way, as described in Lecture 8 (Slides 12-18), simpler, and hopefully better.

The file `thispe25.mat` posted on the ee392m website contains the source data for the identification. To extract the input, output, and sampling time sequences use the following Matlab commands

```
load thispe25.mat
Speed  = get(glass,'InputData');        % plant input
Thickn = get(glass,'OutputData');       % plant output
Tglass = get(glass,'SamplingInstants'); % sampling times
```

The data is noisy and contains offsets and drift. Therefore, the following pre-processing is recommended before you begin other identification steps.

1. Detrend the data using Matlab `detrend` command
2. Perform low pass filtering to get rid of the high-frequency noise. As a low-pass filter, suggest `butter(3,0.2)`.

You will need to accomplish the following steps

(a) Identify a FIR model of the process as explained in Lecture 10, Slide 14. Experiment with the regularization parameter $r$ to get a good estimate. You will find `toeplitz` command useful for setting the regressor matrix. Plot the impulse response estimate. Obtain the step response from the impulse response (use `cumsum`).

(b) Given the step response from Step (a), identify a first order with deadtime model of the process. Perform a nonlinear a parametric fit as described in Lecture 10, Slides 18-20. Find nonlinear least-square estimates by gridding the deadtime (integer 0 to 20 ) and rise time (0.2 to 20 sec) in the model. At each step, use linear regression for estimating the gain. The model should be represented in a `filter` form (numerator, denominator). Give the identified parameters and plot the model step response fitted against the estimate from Step (a).

(c) Using the identified model from Step (b) predict the process output given the input data in the file. Compare the prediction against the output data in the file. Compute correlation coefficient between the predicted and actually observed output signals, in percent. How does this look compared to the Matlab `iddemo` results?

## 2. Dahlin controller

A model for the sideways heat transfer was described in Lecture 2 (Slides 23 and 24) the step response data for the model were dealt with in Assignment 1, Problem 4. An IIR model of the impulse response is computed as described in Lecture 2, Slide 24 by sampling the continuous-time pulse response data at 1 sec interval. This model corresponds to the following sampled-time transfer function

```
   1.797e-009 z^4 + 0.00017 z^3 + 0.003674 z^2 + 0.006498 z + 0.001904
   -------------------------------------------------------------------
          z^5 - 2.338 z^4 + 1.97 z^3 - 0.7206 z^2 + 0.1008 z
```

(a) Build a first order with a deadtime model of the process. Make sure the step response for this reduced model fits well the step response for the given transfer function (closely approximating the step response modeled by the PDEs).

(b) Design a Dahlin controller for the reduced model obtained in (a). Make it an aggressive controller with the reference model time constant equal to the deadtime. Simulate the closed loop responses for the output and control for designed Dahlin controller with the given 'full' model. Compare with the closed-loop responses for the PID controller designed in Assignment 2, Problem 1.

## 3. LP Optimization

Two Crude Petroleum runs a small refinery on the Texas coast. The refinery distills crude petroleum from two sources, Saudi Arabia and Venezuela, into three main products: gasoline, jet fuel, and lubricants. The two crudes differ in chemical composition and thus yield different product mixes.

| Crude | Gasoline yield | Jet fuel yield | Lubricant yield | Availablity, B/ per day | Cost, per B |
|-------|----------------|----------------|-----------------|-------------------------|-------------|
| Saudi | 0.3 | 0.4 | 0.2 | 10000 | $50 |
| Venezuelan | 0.4 | 0.2 | 0.3 | 7500 | $45 |

Comments:
- Process yields add up to 0.9, remaining 10% of each barrel is lost to refining.
- Venezuelan petroleum cost is lower because of the shorter transportation distance.

Delivery contracts with independent distributors require production rates as shown in the table below. How can these requirements be fulfilled most efficiently?

|  | Gasoline | Jet fuel | Lubricant |
|--|----------|----------|-----------|
| Delivery contract, B/ per day | 2000 | 1500 | 500 |

(a) Set up an LP problem (see Lecture 12) and find a solution for minimal oil buying cost to fulfill the contracts.