Spectral Analysis
ELEC 532
Assignment 5

Due: Wednesday 22 March 2000

1. **AR Modeling of Speech for Recognition**

   The data file *Lee Potter's Mystery Utterance* on the web site contains a length 256 real-valued data record of synthetic voiced speech sampled at 10kHz. **Use methods of your choice to select model order and fit an autoregressive model to the data.** Then, use your estimate of the power spectral density to identify the vowel from among the four listed below. Your solution should consist of:

   (a) A listing of the few matlab statements required to fit the model, and a brief description of the method employed.

   (b) A list or plot of values used in determining model order. Read Kay 7.8 to find out about model order selection.

   (c) Your spectrum estimate plotted in dB versus frequency **in Hertz**.

   (d) Identification of the three most significant formant frequencies, in Hertz, as indicated by the moduli and angles of the AR model poles.

   (e) Selection of a vowel from the table below.

   Compare your AR spectrum estimate to a data-windowed periodogram. Comment on the utility of the periodogram for this application.

   Repeat using only 32 data points and compare.

Table 1: Principle Formant Frequencies in Hz for Four Vowels.

vowel	typical word	f_1	f_2	f_3
| æ |	(bat)	660	1720	2410
| a |	(hot)	730	1090	2440
| i |	(beet)	270	2290	3010
| μ |	(boot)	300	870	2240

2. **AR Modeling for Equalization**[1]

   You have been asked to digitally remaster a rare recording of the immortal Italian tenor, Enrico Caruso (1873-1921). You have obtained the original sound recording device from a museum in Milan; data have been generated by using a broadband (i.e., pseudo white noise) signal as input into the device. Your approach is (1) to find an AR model to approximate the second-order statistics of the data and then (2) ameliorate the distortion by filtering with the inverse of the system model.

   The data is available on the Elec 532 WWW site as *Caruso*.

   (a) Compute and plot classical spectral estimates of the data (a basic periodogram and an averaged basic periodogram using 4 blocks of 256 points each).

   (b) Compute and plot the biased estimate of the ACF of the data (the command `xcorr` is useful for this purpose).

   (c) Using the `toeplitz` command, set up and solve the Yule-Walker equations for a linear predictor of order $p = 4$.

   (d) (Optional) Write a Levinson recursion routine and solve the same problem.

   (e) Plot the frequency response of the prediction error filter $|A(f)|^2$ on a log plot.

   (f) Equalize the data by passing it through the prediction error filter (use the command `filter`). Compute and plot classical spectral estimates of the whitened data using the same parameters as in (a).

   (g) Compare your estimate from part (f) with the direct estimate obtained as $\hat{P}_{xx}(f)\,|A(f)|^2$.

   (h) Finally, plot the AR PSD estimate $r_{xx}[0]\,|A(f)|^{-2}$.

   (i) Repeat parts (c)–(h) for $p = 10$ and $p = 100$.

   (j) Now that you have the filter $|A(f)|^2$, what do you do with it to equalize the recordings?

   Include interpretive comments.

3. With your study group, discuss and synthesize the major *themes* of this week of lectures. Turn in a one page summary of your discussion. You need turn in only one summary, but include the names of all group members.

[1] Equalization is used in communication systems to remove distortion by compensating for nonuniform channel gain and multipath effects, and to improve the signal-to-noise if the channel introduces band-limited noise. Equalization (also known as inverse modeling) is also used in echo cancellation in telephone systems, other interference cancellation schemes, adaptive control, speech analysis, and deconvolution, for example.