#### Texas Tech University

#### Department of Electrical and Computer Engineering

#### ECE 4264 / 5364 Digital Signal Processing

#### Fall 2019 Group D1

# Homework 9

Due November 22 before midnight CDT.

Please submit to Blackboard exactly two files:

1. A single ZIP file with all your MATLAB programs, along with any data files necessary to run your programs.
2. A single report document in Word or PDF. Your report should include procedures and solutions to analytical problems, screenshots of results and graphs from programs, and discussions. Please do not include copies of your code in the report.

Submit your solutions to Blackboard by the date and time listed to avoid penalties. This homework is individual. You are welcome to discuss your approach with others, but your answers need to be unique. If your answers are found to be highly similar to others’ or to some material published, you may be subject to a review of academic integrity.

Undergraduate students only need to complete Part 1. Graduate students should complete both Part 1 and Part 2.

## Part 1 (Both ECE 4364 & 5364 students)

### Problem 1 (15 points)

Estimate the power spectral density of the signal in the “test\_signal.mat”, using the Yule-Walker AR (all-pole) method. Note that the Matlab function aryule() implements this methodology. Recall that this signal is known to contain four sinusoids at different frequencies with different amplitudes and is buried in white noise. The test signal is 5 seconds long and is sampled at 500 samples/second.

1. Choose a model order P, estimate the all-pole model that best fits the signal, and plot the frequency response of this model. This should approximate the power spectral density of the signal. Modify P, observe and comment on the behavior.

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**P = 150**

**I graphed the PSD using two different methods. One involving the aryule() function and the other involving the pyulear() function. The same was done with problem 2 for the Burg method. The PSD ended up being the same shape but the scaling was off. As P increase, the resolution of the four signal frequencies increases and as P decreases, the resolution of those same four frequencies decreases and more noise is made present.**

1. What is the minimum model order size P with which you can differentiate the four distinct signal frequencies?

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**P = 75**

**I used a minimum model order of 75 to differentiate between the four frequencies. I tested between 65 and 75 for model order and 75 looked the best in my opinion.**

1. Pick a model size that maximizes the SNR. What is the SNR between the signal frequencies and the highest noise elements, in dB?

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**P = 225**

**I calculated the SNR using the difference between the top and lower powerful frequencies. 225 gave me the best SNR. This SNR was about 5-7 dB.**

1. Comment as to the advantages and disadvantages of this methodology with respect no non-parametric models used in homework 7.

**Nonparametric methodologies are not based on any model and come straight from the fourier transform using FFT and DFT. Parametric methodologies are based on actual models and significantly less data is required to produce the same result. The advantages of working with parametric model include higher quality PSD estimates and lower amounts of data. One disadvantage of the parametric methodology though is that if the model is incorrect, the PSD estimate is wrong.**

### Problem 2 (15 points)

Repeat problem 1 but using the Burg methodology. Note that the Matlab function arburg() implements this methodology.

1. For a given model order P, estimate the all-pole model that best fits the signal. Then plot the frequency response of this model. Modify P and observe the behavior. Comment on any differences observed with respect to the Yule-Walker method.

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**P = 70**

**One big difference from the Yule-AR method was that Burg used a lower P size to differentiate the frequencies and works great with short data sets.**

1. What is the minimum model order size P with which you can differentiate the four distinct signal frequencies?

**A P of 70 was the minimum to differentiate the four frequencies.**

1. What is the best SNR you can get?

**Best SNR I got was between 6-10 dB for each of the signals.**

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### Problem 3 (15 points)

Identify the system in the “hidden\_system.p” using an auto-regressive (all-pole) model. This hidden system is known to be LTI. Your task is to create an all-pole model that behaves similarly to the hidden system. You may use any of the AR methods studied to estimate the model parameters.

1. Select one AR estimation method. Justify your selection.

**I chose the Burg AR estimation method. I mainly chose this due to the higher resolution compared to Yule-Walker.**

1. Generate a random input vector of length N. Start with a large value of N (1 million or so).
2. Select a model order P and estimate the model parameters that best fit the behavior of the system. Then plot the frequency response of the model. Modify P and observe and comment on the behavior.

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**The left graph is the frequency response at P = 9. The right is the PSD at P = 9.**

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**This graph is a realization of just the magnitude response.**

**When P increases, the more distortion is applied to the top part of the filter.**

1. Determine minimum model order P that allows a clear definition of the system behavior. Justify your recommendation.

**P = 9 gave me the minimum model to see what the hidden\_system is doing to a signal. This P provided less distortion on the hidden\_system filter.**

1. Reduce the number of input samples N. Observe and comment on the behavior.

**As the number of input samples N decreases, the amplitude of the filter response increases ever so slightly. When the change is drastic enough such as N is a single digit, the response falls apart altogether.**

1. Recommend a minimum recommended inputs size N. Justify your recommendation.

**Minimum of 60 samples worked for getting the transfer function correct.**

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1. Compare this methodology with the non-parametric methods used in Homework 7. Comment on the advantages and disadvantages of this method.

**I found this method to be simpler to implement compared to using pwelch. This parametric method allows for both a lower amount of computations to be made in order to create the proper PSD. I also found that a lower noise vector was able to be used in this case whereas in the previous homework, the noise vector had to be rather large.**