

## **2.693 (13.998)**

### **Principles of Oceanographic Instrument Systems – Sensors and Measurements**

**Dr. James Irish**

#### **Sample analysis assignments and problem sets**

Analysis #1. –

Get on a computer and work with MATLAB. You may want to work with the tutorial until you feel comfortable with the commands.

A. Create a 512 point long sine wave with amplitude of 2.0 and a period of 32 points. NOTE: first you have to create an array of angles as the argument of the sine wave (create the numbers from 1 to 512, multiply them by two pi and divide by 32 to get the angle series). Take the sine of this and multiply by the amplitude, 2.0, to get your final 512 point series. (You can change the initial phase of the sine wave by adding a constant to the angle series.)

B. Calculate the statistics of the series, i.e. find the maximum, minimum, mean, mean square, root mean square, variance and standard deviation. Some of these are standard MATLAB functions included with the package, and others you will have to create. Do these results make sense with what we have discussed in class?

C. The series you generated is deterministic. Now generate a 512 point random series. The MATLAB random number generator makes a series which has amplitude of 0 to 1.0, so multiply by 0.1 to make a random series of amplitude 0.1, and add this to your sine wave.

D. Now calculate the statistics of this random "noise" series, and the sine wave with the random series added (this series is now random since you can not exactly determine the next value in time). Does this agree with what we have discussed in class.

E. Plot the results of all three series you have created, and discuss the results of this simple exercise in terms of the statistics and your understanding of time series so far.

Analysis #2 -

A. Create two sine waves of the same frequency and but slightly different initial phase. Add in two different random noises, such as a uniform and a normal distribution, and calculate the Auto-covariance and Auto-correlation functions for one of these series.

B. Calculate the Cross-covariance and Cross-correlation functions from these two series.

C. Plot the original time series, the auto- and cross-correlation results. Are the results what you expected from our discussion in class?

Analysis #3 -

A. Create a sinusoidal time series of amplitude 2.5 to which you have added a random component of amplitude 0.2. Note that the length of your series should be a power of two.

B. Calculate and plot the Fourier transform (FFT) of your original series and your noisy series. Does it agree with what you expect?

Analysis #4 -

A. Create a sine wave with noise as we did in assignment 3.

B. Calculate the Fourier coefficients for your sine wave. Is the energy at the frequency it is supposed to be? Is your amplitude and phase properly represented in the Fourier coefficients?

C. Create a 5 point triangular filter of 5 points length. To be normalized for a low pass filter, the weights must sum to one, so the weights are 0.0, 0.25, 0.50, 0.25, 0.0. Using "filter", apply your triangular filter to your sine wave with noise.

D. Plot the initial and filtered series. Does the filter remove some of the high frequency random noise?

E. Using FFT, transform the filter weights (cosine transform since the filter weights are an even function) to get the filter gain (filter response function).

F. Make a log-log plot of your filter's frequency response function. Does it look reasonable to you?

Analysis #5 -

A. Generate two sine waves of the same frequency with different phase, and different random noise added. Plot your results.

B. Calculate the power density spectrum of both series and plot (log-log).

C. Calculate the Coherence squared function and plot (linear coherence and log frequency). Discuss your results?

Analysis #6 –

Given the MATLAB files RESTMP.MAT or RESLAB.MAT on Class account, calculate the frequency response of the temperature sensor by the methods we have discussed. The array "WBO" is the temperature time series that is sampled at times given in array "TIM".

A. Plot out the response to the step function (which was applied at time equal zero) and plot the step. Is this reasonable?

B. Take the first derivative to an impulse response and plot. What is the amplitude of the impulse, and the amplitude of the sensor's response? Does this seem reasonable?

C. Transform to get the response function. Remember this is a complex function with an amplitude gain and phase shift. Plot the response and discuss.

7. An optical decoder is used to digitize the orientation of the compass and vane in the VACM. There are seven tracks on the encoding disk that are each divided into clear and opaque sectors to modulate seven LED-photodiode pairs. It is awkward if two sectors change at once since a slight misalignment in the threshold of the detectors might cause one sector to be detected before the other in either order. The Gray code in a binary code in which only one bit is permitted to change at a time. Using the rule that the lowest order bit possible be changed at each transition, generate the seven bit cyclical Gray code.

8. In the absence of drag, compute the vertical oscillation period (or frequency) of a Swallow float with half the compressibility of sea water.

9. A current meters with recording capacity of 10 million bits is to be deployed for a year. A resolution of 0.1 cm/sec is require and overflowing or overscaling at 25 cm/sec is acceptable. How long must each sample be averaged for? If a time work of 24 bits is added, specify a record format including the time and an array of current samples that is only 10% less efficient. How large a memory is needed to store this array before recording?

10. A 10 kilohm thermistor is to be used to measure microscale ocean temperature fluctuations. No more than 100 microwatts can be dissipated in the thermistor without unacceptable self heating. The expected signal is 1 ppm change in resistance. What is the minimum time that can be taken for the thermistor measurement and still achieve a signal to noise ratio of 0 db (equal signal and noise)? If the thermistor response time to a step change in temperature is 16 ms, how accurately can on interface in temperature be defined when traversed at 30 cm/sec?

11. In an acoustic current meter with 15 cm diameter averaging volume, a 30 cm/sec current is expected. How rapidly must the sensor be sampled to avoid aliasing. If sampled at ten times that rate, what would the spectrum be expected to look like?

12. Vorticity can be measured by sending sound in opposite directions around a triangular path and measuring the difference in travel time for the two directions. Design a scheme for doing this from three buoys, two of which are transponders. Can some or all of them be free drifting?

13. Take a single data set and present it in several different formats. i.e. scatter, contour, surface, 3-D, color/no-color, etc.

14. Take a simple hydrographic data set from Massachusetts Bay that includes ship heave, tide effects, and erroneous data point(s). Present contoured data with and without effects removed, and with contours based on both tight and sparse sampling. Determine causes of differences in results.

15. Select a paper from a refereed journal concerning development or use of a new in situ oceanographic sampling instrument and make a thoughtful critique of the paper and the instrument.

16. Select a refereed paper concerning a field environmental survey of some sort and make a thoughtful critique of the paper and the survey.

17. Research a topic (instrument? survey? data set?) and prepare two presentations: one for a professional audience, one for a lay audience.