**ECE 246/446 –Fall 2014 Computer Project 1 Oct 7, 2014**
**Due (in Class) Nov 4, 2014**

**Part I** Write a matlab function that computes a spectral estimate for a time series $x[n]$ by forming the average:

$$\frac{1}{\text{Sections}}\sum_{n=0}^{\text{Sections}-1}\left|DFT\left\{x\left[(1,2,\ldots,\text{FFTsize})\text{+n}\times\text{skip}\right]\right\}\right|^2 \Big/ \text{FFTsize}$$

i.e. the average of the squared magnitude of the Fourier transforms of the subarrays:

$$\begin{array}{l} [1,\ldots,FFTsize] \\ [1,\ldots,FFTsize]+skip \\ \ldots \\ [1,\ldots,FFTsize]+Sections\times skip \end{array}.$$

The signature of this function should be:

```
function Spectrum =EstimateSpectrum(x,skip,FFTsize)
```

The `Sections` parameter should be computed automatically to be the maximum number of sections that will fit in `x`.

Apply this function to the noise array generated by

```
Noise = .05*(rand(512000,1)-.5);
```

as follows:

```
NoiseSpectrum2048=EstimateSpectrum(Noise,1024,2048);
```

and plot the result. Make sure that the DC value is in the center of the plot, and only include 64 values to the right and left of the DC value in the plot. Describe the plot and explain the range of numeric values.

Next, generate three additional spectral estimates of `Noise` as follows:

```
NoiseSpectrum1024=EstimateSpectrum(Noise,512,1024);
NoiseSpectrum512=EstimateSpectrum(Noise,256,512);
NoiseSpectrum256=EstimateSpectrum(Noise,128,256);
```

Assume that the `Noise` samples are acquired at a 20 MHz sample rate, and plot all four spectral estimates in a single plot that has an x-axis that is labeled in units of MHz. In each case, plot all the frequency components of each spectral estimate. A different color should be used for each spectral estimate and the plot should include a legend identifying the curves.

Describe the differences between the four spectral estimates.

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**Part II** Write a matlab function with the signature

```
function Rp=ShapeRandomProces(N)
```

This function should generate the output signal `Rp` recursively from the input (noise) sequence by setting:

```
Rp[1]=N[1]
Rp[n+1]=N[n+1]-.9*Rp[n]  : n=1,2,…,length(N)-1
```

Apply this function to the noise sequence from part 1 as follows:

```
Rp = ShapeRandomProcess(Noise);
```

and then form four estimates of the the spectrum of `Rp` by using the commands

```
RpSpectrum2048=EstimateSpectrum(Rp,1024,2048);
RpSpectrum1024=EstimateSpectrum(Rp,512,1024);
RpSpectrum512=EstimateSpectrum(Rp,256,512);
RpSpectrum256=EstimateSpectrum(Rp,128,256);
```

Assume that the samples are acquired at a 20 MHz sample rate, and plot all four spectral estimates in a single plot that has an x-axis that is labeled in units of MHz. In each case, plot all the frequency components of each spectral estimate. A different color should be used for each spectral estimate and the plot should include a legend identifying the curves.

Describe the plot and explain the reason for the general shape of the curve. Your explanation should include an analytic derivation of the shape of the curve. Identify the spectral estimate that gives the best approximation of the analytic expression.

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**Part III.** The file `AshokanFarewell.wav` is a stereo file of instrumental music that includes parts for a fiddle (violin) and a guitar. The file is available on blackboard.

You can read this file into matlab with the command

```
AF=wavread('Ashokan Farewell.wav');
```

provided that the wav file has been copied into your working directory. You can then play to the file using the commands

```
player = audioplayer(AF, 44100);
play(player);
```

The number 44,100 is the sample rate (number of samples per second) of the wav file.

As you listen, notice that the instrumental can be divided up into time intervals according to which instruments are active and the sound levels of the instrument. Also note that the `AF` array is about 244 seconds long and has two sequences of sound amplitudes because the wav file is stereo.

Write a matlab function called `PlotSpectra` that computes and plots a separate spectral estimate for each second (i.e. each 44,100 samples) of (one channel of) the wave file as a vertical line in a gray scale image. The spectral estimate for each vertical line should be computed by calling the `EstimateSpectrum` routine from Part I. The signature for `PlotSpectra` function should be

```
function Spectra =PlotSpectra(x,skip,FFTsize,MaxFreq)
```

where the output argument `Spectra` is a two dimensional array in which the first dimension is frequency and the second dimension is time. The frequencies spanning the first dimension of `Spectra` should start at 0 and end at `MaxFreq` (specified in *KHz* ), but the number of frequencies in this range will vary depending on `FFTsize.` The size of the second dimension of `Spectra` is the number of seconds (i.e. the number of intervals of 44,100 samples) in the input array `x.`

The figure produced by `PlotSpectra` should be generated by applying the matlab function `imagesc( )` to the log of the `Spectra` array. The figure axes should be have units of seconds along the horizontal axis, and units of *KHz* along the vertical axis. The image should be displayed using the *jet* colormap.

This type of image is called a *spectragraph*

Form three different spectragraphs using the commands

```
EstimateSpectra(AF(:,1),8192,16384,10);
EstimateSpectra(AF(:,1),2048,4096,10);
EstimateSpectra(AF(:,1),512,256,10);
```

What observations can you make about these images ?.

**Part IV.** Type in the following two matlab functions in separate files (you can cut and paste the text below)

```
function player=runAF(skip,fftSize)

global player

AF=wavread('Ashokan Farewell.wav');
player = audioplayer(AF, 44100);

set(player,'TimerFcn','timerCallback','TimerPeriod',1);

Spectra =PlotSpectra(AF(:,1),skip,fftSize,10);
hold on;

play(player);
```

```
function timerCallback()

global player

nSample=get(player,'currentSample');
plot(floor(nSample/44100)+1,1,'*w','LineWidth',8);
```

The purpose of the `timerCallback()` function is to mark the current location (i.e. the current vertical line) on the spectrograph as the piece is played so that the vertical spectra can be conveniently correlated with the music.

Write a brief analysis of the relationship between the spectra and the music. Try to explain features of the spectragraph in terms of the music. Please be clear, concise and specific. Use the zoom feature in the menu of the matlab figures to examine details of the spectragraph.