EECS C145B / BioE C165 Spring 2003: Problem Set IV Due April 29 2003

Please read the sections describing the rules for working in groups and the grading policy in the course introduction handout.

This is a long problem set. It might be a good idea to delegate questions among members of your group.

Show all code and plots.

Problem 1 (50 points)

You are spying on a foreign government and intercept every email going in and out of their local consulate. One of the incoming emails has a strange binary attachment that even experts cannot decrypt. The subject line of the email is also cryptic: "120 Bohemian points of view, Dr. R.". Something about this subject line reminds you of something you studied years ago but you can't put your finger on it. The consulate does not appear to have a Dr. R. on their staff. Your cryptographers are only able to tell you that the file is a stream of double precision floating point numbers in IEEE big-endian format. You realize you're going to have to knuckle down and figure it out yourself. Crack the code and find out what message is hidden in the file.

Download the attachment at:

`http://muti.lbl.gov/145b/bohemia.bin`

Hint: Use *fread* to read the binary file.

Problem 2 (75 points)

Write a program that generates a Poisson process. The output should be a vector that is -0.99 everywhere except when an event occurs. At event points it should be equal to 0.99 (these values make good use of the dynamic range of the sound card). Make a *wav* file of the sound of the process. Set the rate parameter so you can hear some individual events. Plot the empirically obtained distribution of the times between events. Plot a segment of the output process that shows several successive events.

Possibly useful functions: *rand, expinv, wavwrite, sound, cumsum.*

Problem 3 (30 points)

You have a program that calculates the pseudoinverse. Show analytically how the same program can be used to solve the weighted least squares problem:

$$\boldsymbol{\mu}_{\text{WLS}} = (\mathbf{F}^T \boldsymbol{\Sigma}^{-1} \mathbf{F})^{-1} \mathbf{F}^T \boldsymbol{\Sigma}^{-1} \mathbf{p}$$

Problem 4 (10+20+20+20 points)

1. Use the Matlab command *phantom* to generate a brain phantom of 256×256 pixels.

2. Using the sampling criteria for the Radon transform and the function *radon*, generate a set of projections and plot the sinogram.

3. Using the function:

   `http://muti.lbl.gov/145b/backproj.m`

   reconstruct the imaged distribution using:

   (a) Backprojection of Fourier-filtered projections.

   (b) Fourier-filtered backprojection algorithm

Problem 5 (30+20+20+10+20 bonus points)

A certain tomographic imaging protocol involves taking 16 projections over 180 degrees. Each projection contains 29 bins. You are given a set of projections in the Matlab workspace file:

`http://muti.lbl.gov/145b/sinogram_annulus.mat`

1. Using *radon* calculate the projection geometrical weighting factor matrix $\mathbf{F}$ if you are to reconstruct the image on a 16×16 grid. You should consider using *save* to store this matrix, as it may take a while to generate it. Plot $\mathbf{F}^T\mathbf{F}$ as an image. Describe its structure.

2. Reconstruct the image using the pseudoinverse. Plot the singular value spectrum and choose an appropriate truncation point. Reconstruct using 256 singular vectors and using your chosen truncation point. Compare the two results qualitatively. Explain why truncation helps.

3. Reconstruct the image using the weighted least squares method. Model the projection bin variance as equal to the projection value (Approximation to the Poisson distribution). Use the SSD to determine which reconstruction (LS or WLS) is better.

4. Compare the two reconstructed images with each other and the true image in the variable *im*.

5. Write a function that calculates the Poisson negative log-likelihood function and its gradient. Add the number *eps* to $\boldsymbol{\lambda}$ to prevent logs of zero being taken.