EE257/GP258
Applied Optimization Laboratory

Lab/Homework #2
Handout #6
Due: Thurs., Jan. 24

Problem 1 – Some introductory fortran90 matrix examples.

Fortran 90 has some built-in matrix manipulation routines that are easy to access and use. Of particular interest are the transpose and matrix multiplication operations. For a given matrix m, the function transpose(m) acts as the transpose of matrix m. As for multiplication, the statement c=matmul(a,b) returns the matrix product a*b in the matrix c. Any of these may be vectors instead of matrices if the dimensions are correct.

Matrix inversion is more difficult, so we are proving you with a routine for matrix inversion on the class web site under lab2 in the homework area. Download the file matrixinv.f and append this to your programs in which you need to compute inverse matrices. The syntax for this is

```
call matrixinv(a,b,i,j)
```

which places the inverse of matrix a into the variable matrix b, where i and j are the sizes of the matrix.

i. To see how this works, create the following matrix

```
a  = 1  2  1
     2 -1  3
     1 -1  2
```

and vector x = (1 2 3)

Compute the product a*x.

ii. Compute the inverse of a. Test your result by multiplying a*inverse(a) and see if you get an identity matrix.

Problem 2 – Polynomial curve fit.

Here you will download some noisy data and fit a smooth polynomial to it. Note that you can display vector data using the plotting program xmgr. If you type

```
xmgr filename
```

you will see a plot of a single line of data vs. the point number. If the format of the file is

x1 y1
x2 y2
x3 y3, etc.,

xmgr will plot y vs x. You can also plot multiple lines if the file format is

x1 y1 z1
x2 y2 z2
x3 y3 z3, etc.,

and you invoke xmgr as

xmgr –nxy filename

i. Download the data file lab2prob2.dat from the class web site. Plot the data using xmgr and note that it is noisy.

ii. Compute the van der Monde matrix for a polynomial of order 2 and calculate the fit using the unconstrained inversion method. What are the polynomial coefficients? Plot a single plot with both the original data and the quadratic fit to see how well the fit worked.

Problem 3 – Constrained inversion.

Astronomers use the spectrum of a star to determine its surface temperature because the star's spectrum follows a blackbody radiation law. The surface temperature follows from the approximate law

temperature = 3000 / peak wavelength in micrometers

Measurements are made at discrete spectral values but the response of the instrument can have a large range of wavelengths for each observation. Here suppose we are studying the spectral range of 0.01 to 1.0 micrometers. Suppose further that we use 15 detectors, centered at 0.15, 0.2, 0.25, 0.3, 0.35, 0.4, 0.45, 0.5, 0.55, 0.6, 0.65, 0.7, 0.75, 0.8, and 0.85 micrometers, that have a Gaussian response with standard deviation 0.04 micrometer about the center wavelength. Thus the response for each detector is

detector(lambda) = exp(-(lambda-center)^2/2/0.04e-6^2

We will use noisy measurements at these 15 wavelengths to estimate the star's spectrum.

i. Read in the image file lab2prob3.dat from the web site.

ii. Compute the spectrum using the unconstrained least squares method of problem 2. Compute the spectrum for every 0.01 micrometer over the range of 0.01 to

1.0 micrometers, so there should be 100 points in your solution. Plot this result and see if you can determine the peak of the response.

iii. Now compute the spectrum using constrained linear inversion where the constraint matrix is the minimum power solution, that is, use the identity matrix in the constrained inversion formula. Plot the rms error between the actual data and the estiumate of the data obtained from your spectrum as a function of the multiplier gamma as shown in the notes, and select a value that yields a smooth solution.

What is the peak value? To what temperature does this correspond? Plot both the chosen solution spectrum and the variation of rms error with gamma in your writeup.

Problem 4 – Constrained inversion using smoothness constraints.

Repeat problem 3 but this time use the first differences smoothness constraint instead of minimum power. Submit the corresponding plots to those from the previous problem. How does the rms error vs. gamma curve differ from the one shown previously? Which solution more faithfully shows the true stellar spectrum?