# BME 51:186 — Homework 3

**DUE: October 1, 2004 at start of class**

In this assignment you will look at frequency domain image filtering. For problems 1, 2, and the first few parts of problem 3, hand in a copy of your solutions in class. For the programming part of problem 3, use the MILP environment and use the grade program as you did for assignment 2. **No late homework will be accepted!** The timestamp from the `grade` program will be used to determine which assignments are on time.

Because part of this assignment requires that you devise an algorithm to solve a problem, part of your grade will be based on how well you document your solution and comment the source code that describes the algorithm. If I can't understand your source code and comments, you will not receive full credit, even if the algorithm works.

1. GW problem 4.14
2. GW problem 4.15
3. A technique for acquiring endoscopic images is to couple a lens at the end of the endoscope to a CCD camera via a fiber-optic bundle. Unfortunately, images of this type are usually degraded because the CCD camera has enough resolution to image the individual fibers and the spaces between them, so we end up with an image that shows the individual fibers modulated by the image intensity at that point. Filtering can be used to reduce the severity of this distortion.

   Assume that the fiber bundle produces a sampled version of a continuous image. Model this process as
   $$g(x, y) = s(x, y)f(x, y),$$
   where $g(x, y)$ is the observed (distorted) image and $f(x, y)$ is the continuous space image acquired at the lens. $s(x, y)$ models the sampling by the fiber-optic bundle. Let $s(x, y)$ be a hexagonal arrangement of continuous-space $\delta$-functions that covers the entire image acquisition field of view (you may assume they extend to infinity to make the analysis easier).

   (a) Find an expression for $s(x, y)$, the hexagonal sampling function.

   (b) Find the Fourier transform of $g(x, y)$ in terms of the Fourier transform of $f(x, y)$. Explain your answer.

   (c) Design (on paper) a Butterworth low-pass filter to remove the distortion caused by the sampling function $s(x, y)$. Explain how you chose filter cutoff frequency and filter order.

   (d) Create an MILP function to implement the filter you developed for part c. Make it run as operation 1 in the MILP environment. Apply your filter to the image `airway_before.tif` in the directory `http://www.engineering.uiowa.edu/~bme185/P_185/bronch`. Show images of the bronchoscope spectrum before and after filtering (log magnitude), show an image of your filter frequency response (magnitude), and show the bronchoscope image after the filtering is complete.

   (e) One way to improve the filtered result from part d is to apply a sharpening filter after removing the hexagonal distortion. Create an MILP function (operation 2) to apply unsharp masking, with an adjustable gain parameter, to the smoothed bronchoscope image. Show your results before and after unsharp masking with $a = 0.4$. (Hint: You probably need to zoom in on a small structure to see the improved edge definition.)