Fourier analysis assignment

The assignment for this week is to learn to work with libraries and to do some Fourier analysis. This week's programming assignment is a bit easier than some of the others will be, and since we are going to be using public libraries for it, this week also represents a good opportunity to discuss some issues related to ethics and technology, which is a requirement for the course given that it counts for the Technology and Applied Science requirement, which must be met by those of you who enrolled prior to fall 2012. There will thus be two parts:

Part 1: Write a Fourier transform code, and use it to find a pulsar

In radio astronomy, people often look for pulsars. These are neutron stars that have strong magnetic fields and rotate quickly. The rotating magnetic field produces radiation.[1] The radiation is strong when the magnetic poles are pointed toward the Earth and weak otherwise.

Strong is a relative term, however. Only for the very brightest pulsars can you just plot the brightness as a function of time and see that the flux level is going up and down periodically. The reason is that all real detectors have "noise" components to them. For radio telescopes working at low radio frequencies (e.g. between the FM radio band and the band on which television signals are broadcast), the biggest source of noise is often just thermal noise, because the detectors and electronics cannot be kept at absolute zero. This noise will, to first approximation, occur completely randomly, so it will be spread out uniformly in a Fourier spectrum.

For the purposes of this exercise, we care only about finding the period of the pulsar, and not about finding its phase.[2] For this purpose, the power spectrum is more useful than the Fourier spectrum, so compute the power spectrum as well.

1. Write a subroutine to read in a data set from a file.

2. Look on the GSL web pages to find the right FFT routine to use for the project and figure out how to send data to it and what the data the come back from it mean.

3. Write out the Fourier spectrum and the power spectrum of the pulsar. For this step, you will want to look at the example of how to write to a file rather than to the screen given in the program that generates the fake pulsar data (`fake_pulsar.cc`). If you get to the point where you have something that you think is working, but only writes to the screen, and need some help, this is something you should not hesitate at all to ask for help on.

[1] It's not as simple as dipole radiation, but the details of how the power comes out are still not well understood even by the world's leading experts.

[2] Astronomers often will care about finding the phase, since they might make several observations of the same pulsar and try to determine if the pulse period is changing. Often this shows up most easily by seeing that the phases don't connect up right between two observations rather than seeing small changes in the frequency.

After you have written a program that you think will work, download the test pulsar data set from the course web site. Measure the period of the pulsar, both in units of the time steps in the data set and in real frequency units, assuming that the times in the test pulsar data are written out in seconds. Make plots of the original time series, illustrating that you couldn't pick out the period by eye, and of the power spectrum, showing that with the Fourier transform, the period is obvious.

Part 2: Finish writing your short essay on software licenses

You should have already started writing a short essay on software licenses several weeks ago. This will be due at the same time as your assignment this week.

Challenge problem

I am going to leave this a bit more open-ended this week. A few things you might try are to find data sets with variability on the internet – climate data, stock prices, or whatever else you want and can find easily – and computer power spectra of them; or make some fake data with frequencies above the Nyquist frequency and see what the Fourier transform looks like. After you do those things, do a bit of additional research and reading and try to explain why you see what you see.