Advanced High Performance Computing Exercise Sheet 6

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This exercise sheet focuses on completing the measurement of the power spectrum.

Exercise 1 [1 point] Calculating k

You have already calculated the density field $\rho(\bar{r})$ and converted that to an overdensity $\delta(\bar{r})$. You then calculated the Fourier transform of this to get $\delta(\bar{k})$. The next step is to loop over $\delta(\bar{k})$ and compute k from k_x, k_y and k_z.

To calculate the power spectrum you will need to iterate over the grid which you will recall is $N_{grid} \times N_{grid} \times N_{grid}/2+1$. The index of the grid does not always correspond to the "k"-values (k_x, k_y, k_z) and you need to correct for that:

1. The last dimension goes from 0 to $N_{grid}/2$ (inclusive) and this equals to k_z.

2. For the first and second dimension, the indexes go from 0 to $N_{grid} - 1$ (inclusive), but the corresponding k values should be from 0 to $N_{grid}/2$ (as with the last dimension), but then continue from $-N_{grid}/2 + 1$ to -1. For example, if $N_{grid} = 10$, then indexes from 0 to 9 correspond to k of 0, 1, 2, 3, 4, 5, -4, -3, -2, -1.

Write the loop over x, y and z and calculate k_x, k_y, k_z. Calculating k_z is easy, but you will have to check the x and y range and adjust k_x and k_y if they are in the negative zone. Once you have k_x, k_y and k_z, calculate k using $k = \sqrt{k_x^2 + k_y^2 + k_z^2}$.

Exercise 2 [1 point] Linear Binning

Now you want to bin the values. You will need to create two new vectors `fPower` and `nPower` to contain the power spectrum measurements and the number of measurements in each of the bins. Choose the number of bins to be the same as your grid size and initialize these vectors to zero before your loops above. The measure power is the `norm` of the complex measurement, you can simply use std::norm to get the value.

At the end you want the average power, so make sure you count the number of measurements in each bin while you are adding them. Keep in mind that k is the index into your `fPower` and `nPower` so you will be converting k to an integer (in this exercise with `int(k)`). Also remember that k can be larger than N_{grid} so you need to handle this case. Pay attention to your bounds.

After you have accumulated all of the values, output the average power in each bin. You file should have two columns; column one is k and column two is the $P(k)$ that you measured.

Exercise 3 [1 point] Variable number of Bins

In the last exercise the number of bins was fixed to be the same as the grid width and the index of the bin was simply k, or $i_{bin} = |k|$. To generalize this we introduce the concept of the minimum k (k_{min}) and maximum k (k_{max}), as well as the number of bins (n_{bins}). The width of each bin is defined as follows

$$\delta_{bin} = \frac{k_{max} - k_{min}}{n_{bins}} \tag{1}$$

which for $k_{min} = 0$ simplifies to

$$\delta_{bin} = \frac{k_{max}}{n_{bins}} \tag{2}$$

The index of a bin then becomes

$$i_{bin} = \frac{k - k_{min}}{\delta_{bin}} = \frac{k}{\delta_{bin}} = \frac{k}{k_{max}} \times n_{bins} \tag{3}$$

Implement n_{bins} and produce the same measurement with slightly few bins (e.g. 80 instead of 100). Plot both measurements.

Exercise 4 [2 points] Logarithmic Binning

Modify your code to use logarithmic binning instead of linear binning. This is a simple change to equation 3.

$$i_{bin} = \frac{\log(k)}{log(k_{max})} \times n_{bins} \tag{4}$$

Equation 4 is problematic when $k = 0$, but as discussed this is the DC mode which should be zero by design, so it can be ignored, but you need to handle this case.

Once your code is working, measure the power of the 100^3, 200^3 and 500^3 boxes and plot them together as a log/log plot with the k on the x axis and $P(k)$ on the y axis.