Directed Project 1

Problem Description

Download data file `data.h5`

The downloaded data contains the coordinates (x,y) of a number of particles. Complete the following steps:

1. Load them into Python and plot them to visualize the particles' distribution. Can you say a few things based on your observation?
2. Consider a two-dimensional mesh. The horizontal coordinates (x) are `[-0.5, -0.3, -0.1, 0.1, 0.3, 0.5]`. The vertical coordinates (y) are `[-0.5, -0.3, -0.1, 0.1, 0.3, 0.5]`. Plot the mesh on top of the particle distribution.
3. Develop an indexing system for the mesh cells. The lower left corner cell (enclosed by the intervals `[-0.5,-0.3]` in x and `[-0.5, -0.3]` in y) is indexed as `(0,0)`. The right upper corner cell (enclosed by `[0.3, 0.5]` in x and `[0.3, 0.5]` in y) is index `(4,4)`. See the figure "Distribution of the mesh cells" for an illustration.

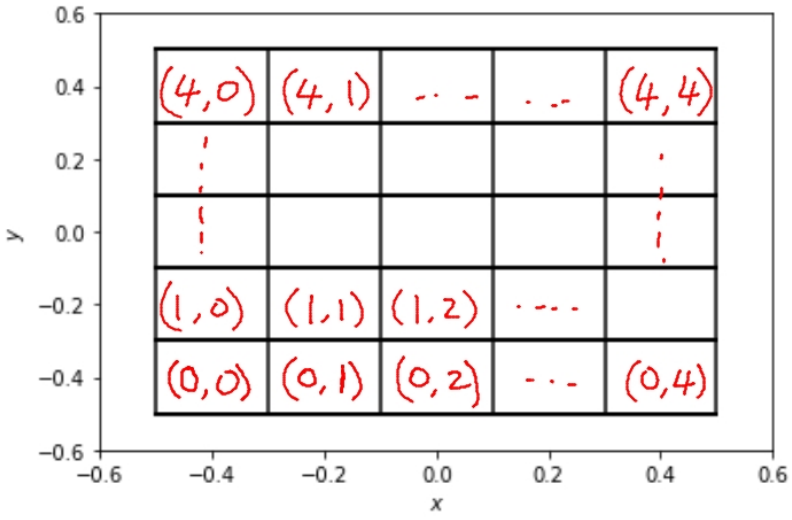

Figure 1: Distribution of the mesh cells

4. Write a Python/Numpy code that determines the number of particles in each cell. Produce an output like the followings (the numbers in the table below are for demonstration only; they are not real answers):

```
Cell index    number of particles

(0,0)          56
(0,1)          122
...            ...
(4,4)          79
```

5. Each of the cell corner is associated with a value as a function of its (x, y) coordinates, e.g.

$f(x, y) = -5(x^2 + y^2)$

For example, at the corner $x = 0.2, y = 0.3$, the value of $f(x, y)$ is $-5\times(0.2^2+0.3^2)$ (by substituting the values of x and y into the formula above).

6. Use linear interpolation to determine the value of a particle, located at coordinate (x_p, y_p) in the following ways:
   - Use linear interpolation to find f_4 using coordinates (y_0, y_1, y_p) and function values f_0 at (x_0, y_0) and f_2 at (x_0, y_1).
   - Use linear interpolation to find f_5 using coordinates (y_0, y_1, y_p) and function values f_1 at (x_1, y_0) and f_3 at (x_1, y_1).
   - Use linear interpolation to find f_p using coordinates (x_0, x_1, x_p) and function values f_4 at (x_0, y_p) and f_5 at (x_1, y_p).

See the figure "Linear interpolation stencil" for an illustration.

Write a Numpy function to compute the interpolated values f_p for all particles.

7. Output the data (x_p, y_p, f_p) (i.e. particle positions and its interpolated function value) from step #6 above to a HDF5 file.

Required uploads

Upload the following items to the class web site:

1. Your Python code - if you are using Jupyter Notebook/Lab, please export your code into a standard Python code so I can run it directly in a text terminal.
2. Compile all of the outputs (except that of step #7) in a presentation-style format (as if you are presenting the data to your boss).
3. The HDF5 file from step #7.

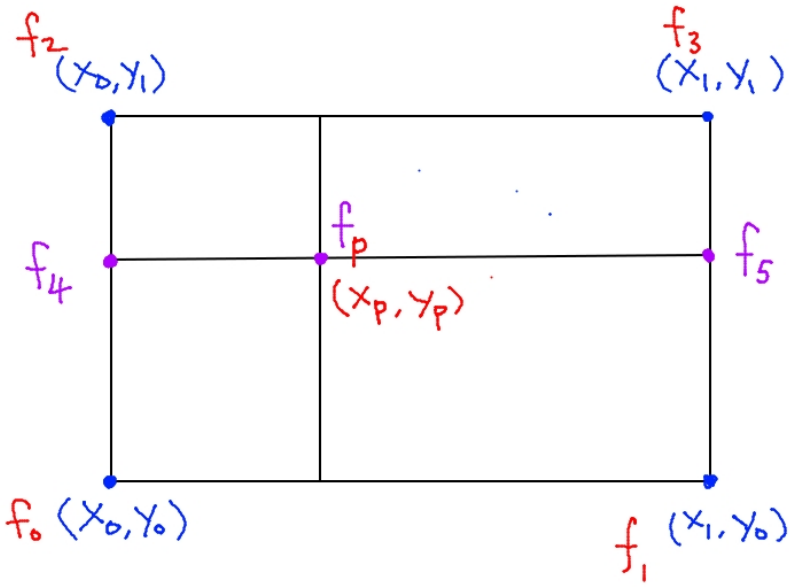

Figure 2: Linear interpolation stencil