CS410P

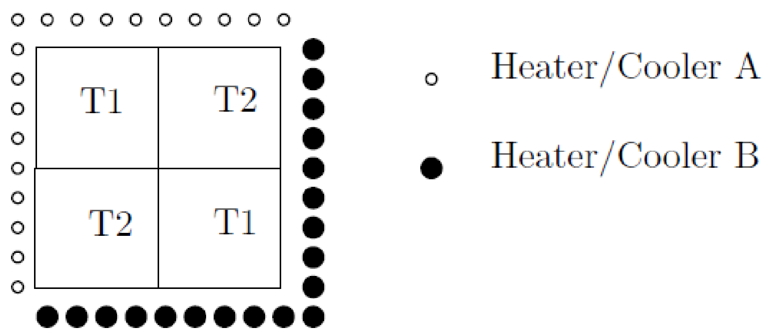
ASSIGNMENT 6P

Purpose

The purpose of this assignment is to have you work with two-dimensional lists in the context of a simulation.

Scenario

The scenario is a heat-flow simulation of the transfer of heat from two sides of a metal plate across the entire plate. A metal plate, as shown below, begins at a pair of fixed temperature. Heater/cooler A is placed up against the top and left (north and west) sides of the plate. Heater/cooler B is placed up against the bottom and right (south and east) sides of the plate. The plate itself starts at two initial temperatures: T1 and T2, as shown below.



For example, the plate might start at T1=10 degrees and at T2=35 degrees, the first heater/cooler might be at 80 degrees and the second heater/cooler might be at 60 degrees. As the simulation starts the sides of the plate will begin to heat up and thus take on temperatures closer to the heaters. This transfer of heat will continue across the plate until it reaches a "stable" temperature, where stable is defined, roughly, as "not changing significantly".

Method

To implement this simulation, we will use a finite state element approximation, that is, we will model the plate with a 2-D list. Only the plate is represented by the 2-D list; thus the heater/coolers are outside (but exactly adjacent to) the list. The plate will be represented by an (8x6) list: 8 rows and 6 columns, thus 48 elements. The temperature of all the plate elements will be initially set to the two initial plate temperatures.

To simulate the transfer of heat, you will traverse the entire list over and over. On each traversal, you will visit each element in your list and compute the new temperature in the following fashion: To determine the new temperature of a specific element, take the average of its four neighbors (north, east, south, west) from the previous cycle. Be careful, if you are updating an element on an edge of the   plate, then you will have only THREE plate values and ONE "outside" value, where an "outside" value is the temperature of one of the heater/coolers. And a corner has two "outside" values. After you complete each traversal you should print out the two 2-D list of updated temperatures. Then replace the values of the old temperature by the new one for the next cycle. The simulation of traversals continues until no element   in the list changes by a significant relative amount, where the significant amount is determined by the value of the last input item (see below). A relative amount means a percent change. Thus a value of .01 signifies a1% change; it does not mean a change of .01 degree.

Data Structure

To store the simulated transfer of heat, you will store the heat temperatures in a pair of 2-D (8x6) list of floats, one for the previous temperature values and the other for the new ones being computed. *(You are not allowed to use packages like numPy to simulate arrays, this will incur a loss of 30 points).*

Input

All input values will come from an input file. Each input file has exactly five floating point values, one per line in this order:
The first heater/cooler temperature (A)
The second heater/cooler temperature (B)
The first initial plate temperature (T1)
The second initial temperature (T2)
The stabilizing criterion value

The stabilizing criterion value is a value to indicate when to stop the simulation. The halting condition is defined as: "If NO element in the list changes by a relative amount MORE THAN the stabilizing criterion then the simulation can stop". (This means that the temperature in the plate is settling down to its final temperature and continued traversals will only slightly change the temperature distribution). See the posted files for examples of input.

Output

The output will first echo the input data then display the heat-plate temperatures. You should display each plate as the temperatures change until the halt criterion is satisfied. Be sure to look at the posted output examples and follow them closely. Make sure that you have the correct number of iterations.
(sample output shown below which shows the inputs as well as the initial plate temperatures, the first plate after simulation begins and the last two plates). Sample output files in the public folder contain complete output.

Details

- Remember that the stabilization criterion is a relative change, not a degree change. Relative change is defined as:

$$|t_o - t_n|/t_o$$

  where t_o is the old temperature and t_n is the new temperature
- You must use at least the following functions (all of them must be commented):

  - read_data(): A function to read input values from a text file, look at the sample input files for data format
  - print_plate(): A function to display the plate temperatures as in the examples. You can assume that the temperature values will be in the range 0 – 99.99 and your display should look good for all temperatures in this range. Your display should look similar to the sample output. Display temperatures with 2 decimal places.
  - initialize_plate(): A function to initialize the plate
  - calculate_new_plate(): A function that does one update of the plate temperatures i.e. one cycle of simulation
  - check_stable_state(): A function that checks to see if your plate has reached stable state or not. *As part of this function, before returning the new plate values should be copied into the old plate to get ready for the next cycle of computations.*
  - You may have as many other functions as you wish in your functions file

- The program must be split into multiple files and you must not use any global variables

- The main function must be the only function in one source (code) file – this file is supplied and is called heatflow.py – you must not modify this file (do not submit it)
- All the other functions should be in a second source (code) file called heatflow_functions.py (you must submit this file)

- As always test your program carefully and follow good programming style.

```
Heater/Cooler Temperature A: 86
Heater/Cooler Temperature B: 13.1
Initial Temperature #1 53.5
Initial Temperature #2 42
Stability Criteria: 0.02

        ### Initial Plate ###
                                         86.00
                        ------------------------------------------------
                           53.50    53.50    53.50    42.00    42.00    42.00
                        ------------------------------------------------
                           53.50    53.50    53.50    42.00    42.00    42.00
                        ------------------------------------------------
                           53.50    53.50    53.50    42.00    42.00    42.00
                        ------------------------------------------------
                           53.50    53.50    53.50    42.00    42.00    42.00
        86.00           ------------------------------------------------          13.10
                           42.00    42.00    42.00    53.50    53.50    53.50
                        ------------------------------------------------
                           42.00    42.00    42.00    53.50    53.50    53.50
                        ------------------------------------------------
                           42.00    42.00    42.00    53.50    53.50    53.50
                        ------------------------------------------------
                           42.00    42.00    42.00    53.50    53.50    53.50
                        ------------------------------------------------
                                         13.10

        ### Plate#: 1 ###
                                         86.00
                        ------------------------------------------------
                           69.75    61.62    58.75    55.88    53.00    45.77
                        ------------------------------------------------
                           61.62    53.50    50.62    44.88    42.00    34.77
                        ------------------------------------------------
                           61.62    53.50    50.62    44.88    42.00    34.77
                        ------------------------------------------------
                           58.75    50.62    47.75    47.75    44.88    37.65
        86.00           ------------------------------------------------          13.10
                           55.88    44.88    47.75    47.75    50.62    40.52
                        ------------------------------------------------
                           53.00    42.00    44.88    50.62    53.50    43.40
                        ------------------------------------------------
                           53.00    42.00    44.88    50.62    53.50    43.40
                        ------------------------------------------------
                           45.77    34.77    37.65    40.52    43.40    33.30
                        ------------------------------------------------
                                         13.10
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### Plate#: 12 ###
                          86.00
                  ------------------------------------------------
                     82.20   78.66   75.02   70.83   63.84   49.51
                  ------------------------------------------------
                     78.98   72.23   66.11   59.04   49.85   35.22
                  ------------------------------------------------
                     76.32   67.61   59.32   51.46   41.55   29.00
                  ------------------------------------------------
                     74.43   63.77   54.95   46.12   37.05   25.77
86.00             ------------------------------------------------        13.10
                     72.25   60.60   50.67   42.49   33.59   23.97
                  ------------------------------------------------
                     69.26   55.75   46.02   37.86   30.45   22.04
                  ------------------------------------------------
                     63.04   48.08   38.47   31.91   25.89   19.78
                  ------------------------------------------------
                     49.18   34.48   27.56   23.35   20.07   16.67
                  ------------------------------------------------
                          13.10
```

```
### Plate#: 13 ###
                          86.00
                  ------------------------------------------------
                     82.41   78.86   75.40   70.97   64.05   49.54
                  ------------------------------------------------
                     79.19   72.84   66.40   59.56   49.91   35.36
                  ------------------------------------------------
                     76.76   67.91   60.03   51.51   41.84   28.91
                  ------------------------------------------------
                     74.59   64.40   54.97   46.49   36.76   25.78
86.00             ------------------------------------------------        13.10
                     72.57   60.61   51.02   42.06   33.49   23.62
                  ------------------------------------------------
                     69.26   55.99   45.69   37.72   29.85   21.82
                  ------------------------------------------------
                     63.13   47.93   38.39   31.39   25.55   19.43
                  ------------------------------------------------
                     49.16   34.48   27.35   23.16   19.75   16.51
                  ------------------------------------------------
                          13.10
```

Grade Key:

A	Printing of plate reasonable showing all temperatures	15
B	Initial plate accurate	15
C	Computation for first cycle accurate	15
D	Computation for a few cycles accurate	15
E	Stability criteria enforced correctly to stop simulation	15
F	Complete program run (with the main module provided)	15
G	Programming style, modularity, comments	10
K	Late Penalty	