

WASHINGTON STATE UNIVERSITY

DATA STRUCTURES FOR DATA ANALYTICS - DA 219

---

# Assignment 1

---

*Professor:*  
your name here

# Overall Assignment

---

In this assignment, you will create the Game of Life invented by John Conway, a mathematician from Cambridge. The game of life is not so much a "game" in the traditional sense, but rather a process that transitions over time according to a few simple rules. The process is set up as a grid of cells, each of which is "alive" or "dead" at a given point in time. At each time step, the cells live or die according to the following rules:

1. A cell that has fewer than two live neighbors dies (due to loneliness)
2. A cell that has more than 3 live neighbors dies (due to over-crowding)
3. A cell that is dead and has exactly 3 live neighbors comes to life
4. All other cells maintain their state

Although these rules seem simple, they give rise to complex and interesting patterns. For more information and a number of interesting patterns see [https://en.wikipedia.org/wiki/Conway%27s\\_Game\\_of\\_Life](https://en.wikipedia.org/wiki/Conway%27s_Game_of_Life)

## Getting Started

---

It is important to break the problem down into pieces and develop the program in stages so that others can understand the code and so that you can ensure that each piece is correct before building on top of it. We will break this problem down into the following steps:

1. Creating a 2d array of cells
2. Displaying the board (in various colors) and updating it with new data
3. Allowing the user to change the state of the cells
4. Implementing the update rules for the "Game of Life"
5. Running and stopping the simulation

Before you start, you need to develop a scheme for keeping track of your data. Basically, the data you need to maintain are the states of all of the cells in the board. We suggest that you keep track of this data in a 2D array of integer values, where 0 represents an empty/dead (off) cell and 1 represents a live (on) cell.

## Creating a 2d board of cells

---

First, in your `life.py` file, copy and test this example function:

```
def createOneRow( n ):
    """ returns rows of n zeros... $i \frac{1}{2}$  You might use
    this as the INNER loop in createBoard """
    R = []
    for col in range(n):
        R += [0]
    return R
```

Another approach would be with list comprehension:

```
def createOneRow( n ):
    """ returns rows of n zeros... $i \frac{1}{2}$  You might use
    this as the INNER loop in createBoard """
    return [ 0 for col in range(n) ]
```

This function offers a starting-point for creating one-dimensional lists – but the same idea applies for building nested list structures arbitrarily deep.

Building on this example, write a function named `createBoard( width, height )` that creates and returns a new 2D list of `height` rows and `width` columns in which all of the data elements are 0 (no graphics quite yet, just a Python list!). For example,

```
>>> createBoard( 3, 3 )
[ [0,0,0], [0,0,0], [0,0,0] ]
```

## Tips

One approach to `createBoard` to use a pair of nested loops: the outer one for the rows, and the inner one for the columns (note that you can use `createRow` as the inner loop). Then, the overall 2d array would accumulate those rows one at a time (within the loop) until it was the correct size. Note that just as

```
R += [0]
```

adds a zero to the end of the list (row) `R`, by the same token,

```
B += [ [0,0,0] ]
```

adds a row of three zeros to the end of list (board) `B`. When you write `createBoard`, that row will have a name (maybe `R`), rather than hand-typed values.

## Displaying your 2d board of cells

---

You no doubt noticed that when Python prints a 2d list, it blithely ignores its 2d structure and flattens it out into one line (perhaps wrapping, if needed). In order to display your board in 2d using the `csplot` graphics module, `csplot.py`. Display the file in your browser and “Save As” `csplot.py`. A convenient place to download `csplot.py` is to your desktop. Though the desktop is easy, any folder you choose is OK. Wherever you put it, you will need your `life.py` file to be in the same folder as `csplot.py`.

Next, in order to use the functions in `csplot`, include the following line at the top of your `life.py` file:

```
import csplot
```

Now, once you run your `life.py` file, you should be able to create and display a 2d array with

```
B = createBoard(10,10)
csplot.show(B)
```

You may need to sleep the program so that it doesn’t just show the board and quit. This way you can see what it looks like. You will see a rather desolate-looking board as seen in Figure 1.

This `csplot` window will not close unless you use the `done()` method. To refresh the window you can use:

```
csplot.update()
```

To close the window, type:

```
csplot.done()
```

and then click the red X in the upper left (or right) corner of the `csplot` window.

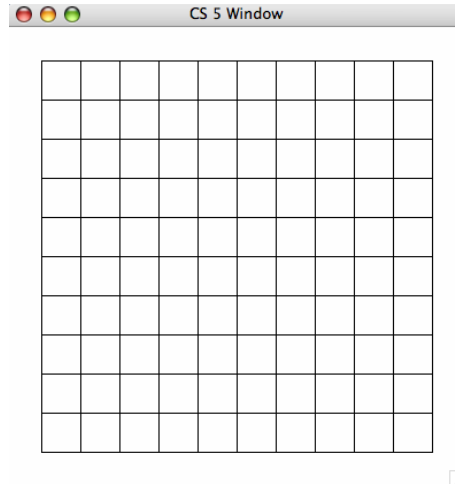


Figure 1: Empty Board

## Adding patterns to your 2d board of cells

In order to get used to using 2d arrays of data and writing functions that modify arrays rather than return them, copy this function named `update1( B )` into your file:

```
def update1( B ):
    """ Takes an empty board as input and modifies that
    board so that it has a diagonal strip of "on" cells
    """
    width = len(B[0])
    height = len(B)

    for row in range(height):
        for col in range(width):
            if row == col:
                B[row][col] = 1
            else:
                B[row][col] = 0 # else not needed here, but
                               # adds clarity
```

This function, `update1` takes as input a blank 2d array of data, `B`. Then, it changes some of that data so that `B` becomes a board whose cells are empty *except for the diagonal* where `row == col`. Note that it **does not return anything**. Also note that we determine the height and width of the board directly from the board itself.

Try displaying the result with

```
B = createBoard(10,10)
update1(B)
cspplot.show(B)
```

**Warning!** The coordinate system of Python's printing and `cspplot`'s graphics system have the rows going in opposite directions. That is, when you print a 2d array (list of lists), the zeroth row is at the top, then the first row is next, and so on. However, `cspplot` uses mathematical coordinates (rows increase along the y-axis and columns increase along the x-axis), so that the zeroth row is at the bottom, the first row is the second-from-bottom, and so on. Thus, when you display this new board, you should get a window that looks something like Figure 2.

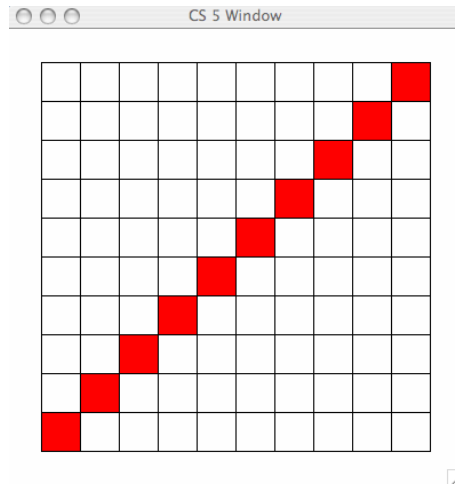


Figure 2: Diagonal Board

Based on the example of `update1`, write a variation named `update2( B )` which returns a board of all live cells, except for a one-cell-wide border of empty cells around the entire edge of the 2d array. Copy-and-paste is your friend! For example, when you run:

```
B = createBoard(10,10)
update2(B)
csplot.show(B)
```

you should get a window that looks something like Figure 3.

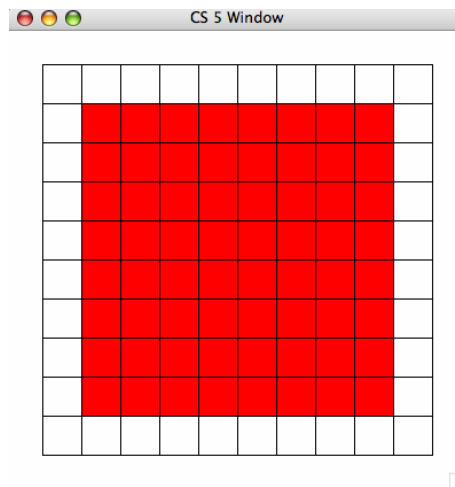


Figure 3: Almost Full Board

Next, create a function named `updateRandom( B )` which takes a board `B` and mutates that board to contain one-cell-wide border of empty cells around the entire edge of the 2d array, just as in the previous case. However, each of the inner cells should be randomly chosen to be live or empty. Recall that `random.choice( [0,1] )` will help here – and that you will need to include the line `import random` somewhere near the top of your file. One possible such board is in Figure 4.

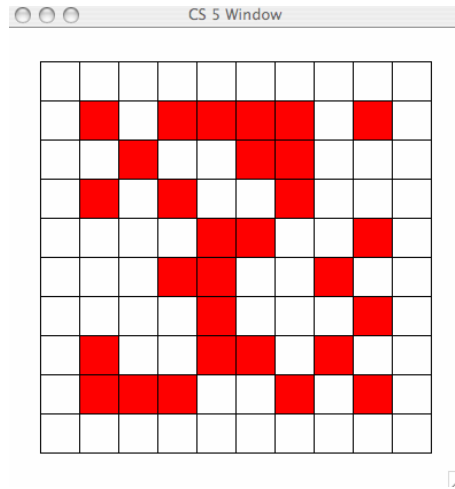


Figure 4: Random Board

## Creating a new “board” from an old one

---

None of the update functions so far depends on a previous “generation” of cells. For our life game we need to update the cells from one generation to modify a NEW board in the subsequent generation.

Write a function `updateReversed( oldB, newB )` that takes an old board and a blank new board and *modifies* the `newB` such that each cell is the “opposite” of `oldB`’s cells. That is, where `oldB[row][col]` is a 1, the new board’s value will be a zero - and vice versa. This function should not return anything. However, keep the outermost edge of cells empty, regardless of their state in the original board - this will help when implementing Life, because it will prevent index out-of-bounds errors.

Recall that you can obtain the width and height from `oldB`:

```
width = len(oldB[0])
height = len(oldB)
```

Try out your `updateReversed` by displaying an example:

```
B = createBoard(10,10)
updateRandom( B )
csplot.show( B )
newB = createBoard( 10, 10 ) # makes newB reference a NEW board...
updateReversed(B, newB)
csplot.show( newB )
```

It’s important that you first make a NEW array of data to pass into the `updateReversed` function. You might point out that it would be possible to simply change the input `oldB`, rather than have two inputs - this is true for the reversed-board example, but not true when implementing the rules of the Game of Life. There, you will need new data on which to place each subsequent generation.

## Writing a Life-updating loop

---

To start updating one generation of cells to the next, read over the following skeleton and then adapt - or simply copy - it into your `life.py` file:

```
import time

def life( width, height ):
    """ will become John Conway's Game of Life... """
    B = createBoard( width, height )
    updateRandom( B )

    while True: # loop forever
        csplot.show(B) # show current B
        time.sleep(0.25) # pause a bit
        oldB = B # just a reminder for us humans
        B = createBoard(width, height) # creates a new board
        updateReversed( oldB, B ) # sets the new board correctly
```

Be sure to import `time`, as noted above the function. The while loop here will run forever - or until you hit `control-c` and will continue to display reversing boards as it goes.

## Adding some user input

---

For debugging and increased user control it will be important to allow the user to specify which cells are on and which are off at the beginning of the simulation. To allow this control, copy and paste the following code at the end of your `life.py` file.

```
def life( width, height ):
    """ will become John Conway's Game of Life... """
    B = createBoard( width, height )
    csplot.showAndClickInIdle(B)

    while True: # run forever
        csplot.show(B) # show current B
        time.sleep(0.25) # pause a bit
        oldB = B # just a reminder for us humans
        B = createBoard(width, height) # creates a new board
        updateReversed( oldB, B ) # sets the new board correctly
```

Here's what should happen when you run this function (e.g. by calling `life(10, 10)`). You will see a blank 10x10 grid appear, but this grid will not update automatically as before. Instead, you should click on the display window so that it is the current top window. Then, hold down the `s` key and click inside one or more of the cells in the display. You should see those cells change from live to empty and vice-versa. Once you're ready, `close` the display window, and you will see another display window appear, starting with the board that you created by clicking (NOT the original blank board) and automatically updating as before.

## Game of Life (Finally)

---

So, for this step, change your life function so that it calls a new function named `updateNextLife( oldB, newB )` in place of `updateReversed`, above. Then, implement the `updateNextLife( oldB, newB )` function so that it sets each cell in the new data according to the updating rules based on the old generation, `oldB`:

1. A cell that has fewer than two live neighbors dies (because of loneliness)
2. A cell that has more than 3 live neighbors dies (because of over-crowding)
3. A cell that is dead and has exactly 3 live neighbors comes to life
4. All other cells maintain their state

As suggested in `updateReversed`, always keep all of the outer-edge cells empty. This is simply a matter of limiting your loops to an appropriate range. However, it greatly simplifies the four update rules, above, because it means that you will only update the interior cells, all of which have a full set of eight neighbors. You may want to write a helper function, `countNeighbors` for example, for determining the number of live neighbors for a cell in the board at a particular row and col.

## Hints

---

Count neighbors only in the old generation `oldB`. Change only the new generation, `newB`.

- Be sure to set every value of `newB` (the new data), whether or not it differs from `oldB`.
- A cell is NOT a neighbor of itself.
- A 2x2 square of cells is statically stable (if isolated) - you might try it on a small grid for testing purposes
- A 3x1 line of cells oscillates with period 2 (if isolated) - also a good pattern to test.

Once your Game of Life is working, look for some of the other common patterns, e.g., other statically stable forms ("rocks"), as well as oscillators ("plants") and others that will move across the screen, known as gliders ("animals/birds").

## Rubric

---

10% Create an empty 2d board

10% Able to properly display the board (using `csplot`)

10% `update1()`

10% `update2()`

10% `updateReversed()`

20% Successful loop with user input

30% `updateNextLife()` with 3 different examples

### What to turn in:

- `life.py`