Lab 4: Six Double-Oh Mines

The questions below are due on Friday March 06, 2020; 04:00:00 PM.

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1) Preparation

This lab assumes you have Python 3.6 or later installed on your machine.

The following file contains code and other resources as a starting point for this lab: `lab4.zip`

Most of your changes should be made to `lab.py`, which you will submit at the end of this lab. Importantly, you should not add any imports to the file.

You can also see and participate in online discussion about this lab in the "Lab 4" Category in the forum.

This lab is worth a total of 4 points. Your score for the lab is based on:

- correctly answering the questions throughout this page (0.5 points)
- passing the `test.py` tests (1.5 points), and
- a brief "checkoff" conversation with a staff member to discuss your work, and a review of your code's clarity/style (2 points).

The questions in section 3 on this page are due before lecture, at 1:30pm on Monday, 2 Mar. The remaining questions on this page (including your code submission) are due at 4pm on Friday, 6 Mar. Because of the quiz on 11 Mar, checkoffs are due at 4pm on *Friday, 13 Mar*.

2) Introduction

International *Mines* tournaments have declined in popularity lately, but we're predicting a resurgence in popularity (maybe the next tournament could be even bigger than the legendary Budapest 2005 tournament?!). In anticipation of just such a resurgence, your roommate has written an implementation of the *Mines* game. In order to prepare *yourself*, you decide to look over their implementation in detail.

2.1) *Mines*

Mines is played on a rectangular $n \times m$ board (where n indicates the number of rows and m the number of columns), covered with 1×1 square tiles. Some of these tiles hide secretly buried mines; all the other squares are safe (and, generally, relative to the size of the board, only a small number of squares contain a bomb). On each turn, the player removes one tile, revealing either a mine or a safe square. The game is won when all safe tiles have been removed, without revealing a single mine, and it is lost if a mine is revealed.

The game wouldn't be much of a game at all if it only involved random guessing, so the following twist is added: when a safe square is revealed, that square is additionally inscribed with a number between 0 and 8, indicating the number of surrounding mines (when rendering the board, `0` is replaced by a blank). Additionally, any time a `0` is revealed (a square surrounded by no mines), the surrounding squares are also automatically revealed (they are, by definition, safe).

3) An Implementation of *Mines*

3.1) Game state

The state of an ongoing *Mines* game is represented as a dictionary with the following four keys:

- `'dimensions'`: a tuple containing the board's dimensions `(nrows, ncolumns)`
- `'board'`: a 2-dimensional array (implemented using nested lists) of integers and strings. `game['board'][r][c]` is `'.'` if square (r, c) contains a bomb, and it is a number indicating the number of neighboring bombs otherwise.
- `'mask'`: a 2-dimensional array (implemented using nested lists) of Booleans. `game['mask'][r][c]` indicates whether the contents of square (r, c) are visible to the player.
- `'state'`: a string containing the state of the game (`'ongoing'` if the game is in progress, `'victory'` if the game has been won, and `'defeat'` if the game has been lost). The state of a new game is *always* `'ongoing'`.

For example, the following is a valid *Mines* game state:

```
{
    'dimensions': (4, 3),
    'board': [[1,  '.',  2], [1,   2,  '.'], [1,   2,   1], ['.', 1,   0]],
    'mask': [[True, False, False], [False, True, False], [False, True, True], [False, True, True]],
    'state': 'ongoing',
}
```

The `dump` function (provided in `lab.py`) might be useful as you work through the exercises below. (You need not modify this function in any of the following sections.)

3.2) Game Logic

The game is implemented via four functions in `lab.py`:

- `new_game_2d` creates a new object to represent a game.
- `dig_2d` implements the digging logic (updating the game state if necessary) and returns the number of new tiles revealed from that move.
- `render_2d` renders the game into a 2D grid (for display)
- `render_ascii` renders a game state as ASCII art

Each of these functions is documented in detail in `lab.py`. Notice how each function comes with a detailed docstring documenting what it does.

3.3) An example game

This section runs through an example game, showing which functions are called and what they should return in each case.

Calling `new_game_2d` produces a new game object as described above:

```
>>> game = new_game_2d(6, 6, [(3, 0), (0, 5), (1, 3), (2, 3)])
>>> dump(game)
board:
    [0, 0, 1, 1, 2, '.']
    [0, 0, 2, '.', 3, 1]
    [1, 1, 2, '.', 2, 0]
    ['.', 1, 1, 1, 1, 0]
    [1, 1, 0, 0, 0, 0]
    [0, 0, 0, 0, 0, 0]
dimensions: (6, 6)
mask:
    [False, False, False, False, False, False]
    [False, False, False, False, False, False]
    [False, False, False, False, False, False]
    [False, False, False, False, False, False]
    [False, False, False, False, False, False]
    [False, False, False, False, False, False]
state: ongoing
>>> render_2d(game)
[['_', '_', '_', '_', '_', '_'],
 ['_', '_', '_', '_', '_', '_'],
 ['_', '_', '_', '_', '_', '_'],
 ['_', '_', '_', '_', '_', '_'],
 ['_', '_', '_', '_', '_', '_'],
 ['_', '_', '_', '_', '_', '_']]
```

Assume the player first digs at `(1, 0)` by invoking the `dig_2d` method. The return value `9` indicates that 9 squares were revealed.

```
>>> dig_2d(game, 1, 0)
9
>>> dump(game)
board:
    [0, 0, 1, 1, 2, '.']
    [0, 0, 2, '.', 3, 1]
    [1, 1, 2, '.', 2, 0]
    ['.', 1, 1, 1, 1, 0]
    [1, 1, 0, 0, 0, 0]
    [0, 0, 0, 0, 0, 0]
dimensions: (6, 6)
```

```
mask:
    [True, True, True, False, False, False]
    [True, True, True, False, False, False]
    [True, True, True, False, False, False]
    [False, False, False, False, False, False]
    [False, False, False, False, False, False]
    [False, False, False, False, False, False]
state: ongoing
>>> render_2d(game)
[[' ', ' ', '1', '_', '_', '_'],
 [' ', ' ', '2', '_', '_', '_'],
 ['1', '1', '2', '_', '_', '_'],
 ['_', '_', '_', '_', '_', '_'],
 ['_', '_', '_', '_', '_', '_'],
 ['_', '_', '_', '_', '_', '_']]
```

...then at `(5, 4)` (which reveals 21 new squares):

```
>>> dig_2d(game, 5, 4)
21
>>> dump(game)
board:
    [0, 0, 1, 1, 2, '.']
    [0, 0, 2, '.', 3, 1]
    [1, 1, 2, '.', 2, 0]
    ['.', 1, 1, 1, 1, 0]
    [1, 1, 0, 0, 0, 0]
    [0, 0, 0, 0, 0, 0]
dimensions: (6, 6)
mask:
    [True, True, True, False, False, False]
    [True, True, True, False, True, True]
    [True, True, True, False, True, True]
    [False, True, True, True, True, True]
    [True, True, True, True, True, True]
    [True, True, True, True, True, True]
state: ongoing
>>> render_2d(game)
[[' ', ' ', '1', '_', '_', '_'],
 [' ', ' ', '2', '_', '3', '1'],
 ['1', '1', '2', '_', '2', ' '],
 ['_', '1', '1', '1', '1', ' '],
 ['1', '1', ' ', ' ', ' ', ' '],
 [' ', ' ', ' ', ' ', ' ', ' ']]
```

Emboldened by this success, the player then makes a fatal mistake and digs at `(0, 5)`, revealing a bomb:

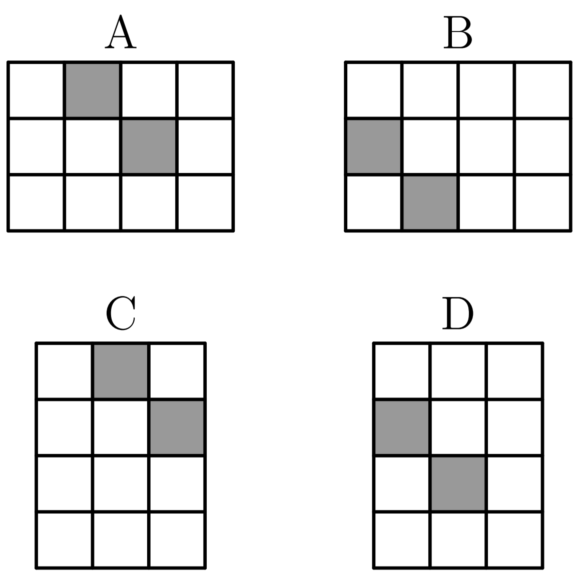
```
>>> dig_2d(game, 0, 5)
1
>>> dump(game)
board:
    [0, 0, 1, 1, 2, '.']
    [0, 0, 2, '.', 3, 1]
    [1, 1, 2, '.', 2, 0]
    ['.', 1, 1, 1, 1, 0]
    [1, 1, 0, 0, 0, 0]
    [0, 0, 0, 0, 0, 0]
dimensions: (6, 6)
mask:
    [True, True, True, False, False, True]
    [True, True, True, False, True, True]
    [True, True, True, False, True, True]
    [False, True, True, True, True, True]
    [True, True, True, True, True, True]
```

```
    [True, True, True, True, True, True]
state: defeat
>>> render_2d(game)
[[' ', ' ', '1', '_', '_', '.'],
 [' ', ' ', '2', '_', '3', '1'],
 ['1', '1', '2', '_', '2', ' '],
 ['_', '1', '1', '1', '1', ' '],
 ['1', '1', ' ', ' ', ' ', ' '],
 [' ', ' ', ' ', ' ', ' ', ' ']]
```

3.4) Check Yourself

Before we dive in to the code, answer the following questions about the representations and operations described above.

Consider the following four boards, where grey boxes represent bomb locations and white boxes represent open squares:



Which of these would result from calling `new_game_2d(3, 4, [(1, 2), (0, 1)])`?

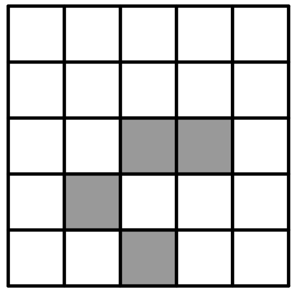
A

Submit

You have submitted this assignment 1 time.

This question is due on Friday March 06, 2020 at 04:00:00 PM.

A new game is created with `5, 5`, and a list `b` passed in as arguments, and it creates the following board layout, where grey squares represent bombs and white squares represent open spaces:



What was the value of `b` that led to this board?

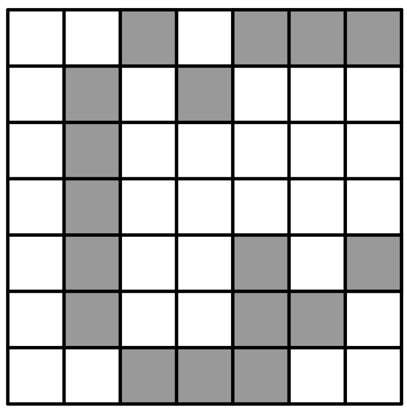
[(2, 2), (2,3), (3, 1), (4, 2)]

Submit

You have submitted this assignment 1 time.

This question is due on Friday March 06, 2020 at 04:00:00 PM.

Consider the following board, where grey squares represent bombs and white squares represent open spaces. Assuming that no squares had previously been revealed, if a player were to dig at location `(3, 0)`, how many squares in total would be revealed?



Enter an integer in the box:

1

Submit

You have submitted this assignment 5 times.

This question is due on Friday March 06, 2020 at 04:00:00 PM.

On the same board, if a player were to dig at location `(2, 6)`, how many new squares would be revealed? Enter an integer in the box:

9

Submit

You have submitted this assignment 2 times.

This question is due on Friday March 06, 2020 at 04:00:00 PM.

3.5) What you need to do

As usual, you will need to edit `lab.py` to complete this assignment. However, the nature of your changes to that file are somewhat different in this lab.

`lab.py` contains a nearly complete implementation of the *Mines* game. Your job in this part of the lab is twofold:

1. Complete the implementation of *Mines* in `lab.py` by writing the `render` and `render_ascii` functions, and
2. Refactor the existing implementation of *Mines* to make it easier to read/understand, and fix any errors you find

Note that one of the test cases in `test.py` is designed to make sure that every function in `lab.py` has a docstring, so if you introduce any new helper functions, you should make sure to write an appropriate docstring for each!

3.5.1) Render

Your first task is to complete the definitions of the `render_2d` and `render_ascii` methods in `lab.py`. The details of the desired behavior for each function is described in that function's docstring. In addition, each offers a few small tests (in the form of doctests), which you can use as basic sanity checks.

Note that you can run the doctests without running `test.py` by running `python3 lab.py`. It is the lines at the bottom of `lab.py` that enable this behavior. You are also, of course, welcome to add additional doctests of your own.

Here is how the output of `render_ascii` might look (with `xray=True`):

```
1.1112.1 1112..1   1.22.11...1
2221.211 1.12.31   112.2112432
1.111211 111111      222   2.2
111  1.1         111 1.1  14.3
   123211221 11112.1 111  2..2
   1..212..1 1.11.21      2.31
   1223.32221211111       111
      2.3111.1  111111111
  111 112.1111  1.11.22.21111
  1.1   111     111112.4.11.1
11211                12.323342
1.1111                113.3...
1122.1       111        2.33.3
  2.31 111   1.1        111222
112.2  1.1   11211111    112.1
.1111  111     1.11.1    1.211
```

Note that you can make a new line in Python with the character `"\n"`. For example

```
>>> print("Hello World\nHello World")
Hello World
Hello World
```

Once you have completed these functions, you can play the game in the browser by running `server_2d.py` and connecting to `localhost:6009`.

3.5.2) Refactor

The implementation provided in `lab.py` is entirely correct, but it is not written in a style that is particularly conducive to being read, understood, modified, or debugged. Your next task for this lab is to refactor the given code (i.e., to rewrite it so that it is expressed in a more concise, efficient, or understandable way).

In doing so, try to look for opportunities to avoid code repetition by introducing new loops and/or helper functions (among other things). Look also for opportunities to avoid redundant computation. There is a test case in `test.py` that makes sure that each function/method in the implementation has a docstring. If you decide to add any new helper methods/functions while refactoring, please give them an appropriate docstring.

If you get stuck looking for opportunities for stylistic improvement, take a look at some of the suggestions we give, on **this "hints" page**; and you may also find it helpful to read through the **section of the course notes on style** for more suggestions.

As you are refactoring the existing code, you can/should regularly run the doctests (and/or `test.py`) to make sure that your reorganization is not introducing errors into the existing code. You can also use the user interface to help find and fix bugs, and you are strongly encouraged to add some test cases of your own.

You should make a note of the things you found objectionable about the original code, as well as the changes that you made along the way, and you should be prepared to discuss these during your checkoff.

4) *HyperMines* (N-dimensional Mines)

Now that we've mastered 2-dimensional *Mines*, we're going to add a little twist `:)`

Rather than playing on 2-dimensional boards, we're going to extend our *Mines* game to work on higher-dimensional boards. In this variant, which we'll call *HyperMines*, everything works just the same as in *Mines*, except for the fact that each cell has up to $3^n - 1$ neighbors, instead of 8 (where n is the dimensionality of the space we're playing in).

4.1) Game Representation and Flow

4.1.1) Game state

Similarly to our 2-D representation, we will represent games as dictionaries, each of which should contain the following four keys:

- `'dimensions'`, the board's dimensions (an arbitrary tuple of positive integers)
- `'board'`, an N-dimensional array (implemented using nested lists) of integers and strings. In an game called `g`, `g['board'][x_0][...][x_k]` is `"."` if the square with coordinate $(x_0, \ldots, x_k)$ contains a bomb.
- `'mask'`, an N-dimensional array (implemeted using nested lists) of Booleans. In a game called `g`, `g['mask'][x_0][...][x_k]` indicates whether the contents of square $(x_0, \ldots, x_k)$ are visible to the player.
- `'state'`, a string containing the state of the game: `'ongoing'` if the game is in progress, `'victory'` if the game has been won, and `'defeat'` if the game has been lost. The state of a new game is *always* `'ongoing'`.

For example, the following is a valid *HyperMines* game state:

```
{
    'dimensions': (4, 3, 2),
    'board': [[[1, 1], ['.', 2], [2, 2]], [[1, 1], [2, 2], ['.', 2]],
              [[1, 1], [2, 2], [1, 1]], [[1, '.'], [1, 1], [0, 0]]],
    'mask': [[[True, False], [False, False], [False, False]], [[False, False], [True, False], [False, False]],
             [[False, False], [True, True], [True, True]], [[False, False], [True, True], [True, True]]],
    'state': 'ongoing',
}
```

Again, you may find the `dump` function (included in `lab.py`) useful to print game states.

4.1.2) Testing

The test cases we will use to check your code in this lab are pretty complex, and so they are difficult to reason about.

To this end, it is **strongly encouraged**, before you dive into the code, to create some test cases of your own in `test.py`, to handle some more straightforward cases that are easier to reason about. For example, you may wish to include some tests on smaller boards. One suggestion would be to make one test for a 1-D game, one for a 2-D game, and one for a 3-D game. Each test could create a new game and perform at least 2 consecutive digs on that game, with different expected behaviors.

4.1.3) An example game

This section runs through an example game in 3D, showing which functions are called and what they should return in each case. To help understand what happens, calls to `dump(game)` are inserted after each state-modifying step.

```
>>> game = new_game_nd((3,3,2),[(1,2,0)])
>>> dump(game)
board:
    [[0, 0], [1, 1], [1, 1]]
    [[0, 0], [1, 1], ['.', 1]]
    [[0, 0], [1, 1], [1, 1]]
dimensions: (3, 3, 2)
mask:
    [[False, False], [False, False], [False, False]]
    [[False, False], [False, False], [False, False]]
    [[False, False], [False, False], [False, False]]
state: ongoing
```

The player tries digging at `(2,1,0)`, which reveals 1 tile.

```
>>> dig_nd(game, (2,1,0))
1
>>> dump(game)
board:
    [[0, 0], [1, 1], [1, 1]]
    [[0, 0], [1, 1], ['.', 1]]
    [[0, 0], [1, 1], [1, 1]]
dimensions: (3, 3, 2)
mask:
    [[False, False], [False, False], [False, False]]
    [[False, False], [False, False], [False, False]]
    [[False, False], [True, False], [False, False]]
state: ongoing
```

... then at `(0,0,0)` which reveals 11 new tiles:

```
>>> dig_nd(game, (0,0,0))
11
>>> dump(game)
board:
    [[0, 0], [1, 1], [1, 1]]
    [[0, 0], [1, 1], ['.', 1]]
    [[0, 0], [1, 1], [1, 1]]
dimensions: (3, 3, 2)
mask:
    [[True, True], [True, True], [False, False]]
```

```
    [[True, True], [True, True], [False, False]]
    [[True, True], [True, True], [False, False]]
state: ongoing
```

Emboldened by this success, the player then makes a fatal mistake and digs at `(1,2,0)`, revealing a bomb:

```
>>> dig_nd(game, (1,2,0))
1
>>> dump(game)
board:
    [[0, 0], [1, 1], [1, 1]]
    [[0, 0], [1, 1], ['.', 1]]
    [[0, 0], [1, 1], [1, 1]]
dimensions: (3, 3, 2)
mask:
    [[True, True], [True, True], [False, False]]
    [[True, True], [True, True], [True, False]]
    [[True, True], [True, True], [False, False]]
state: defeat
```

4.1.4) Check Yourself

To get a feel for working with an arbitrary number of dimensions, answer the following few questions about determining cells' neighbors.

For these questions, it is okay to consider a cell to be its own neighbor, and it is also okay to consider it not to be its own neighbor. Depending on the structure of the rest of your code when implementing this or similar behaviors for lab 4, you might wish to consider a cell to be its own neighbor, or you may not.

In a one-dimensional game with dimensions of `(10,)`, what are the neighbors of the coordinates `(5,)`? Enter a Python list of coordinates below:

[(4,), (5,), (6,)]

Submit

You have submitted this assignment 4 times.

This question is due on Friday March 06, 2020 at 04:00:00 PM.

In a two-dimensional game with dimensions of `(10, 20)`, what are the neighbors of the coordinates `(5, 13)`? Enter a Python list of coordinates below:

[(4, 12), (4, 13), (4, 14), (5, 12), (5, 13), (5, 14), (6, 12), (6,

Submit

You have submitted this assignment 2 times.

This question is due on Friday March 06, 2020 at 04:00:00 PM.

In a three-dimensional game with dimensions of `(10, 20, 3)`, what are the neighbors of the coordinates `(5, 13, 0)`? Enter a Python list of coordinates below:

[(4, 12, 0), (4, 12, 1), (4, 13, 0), (4, 13, 1), (4, 14, 0), (4, 14,

Submit

You have submitted this assignment 1 time.

This question is due on Friday March 06, 2020 at 04:00:00 PM.

Take a careful look at your results for these questions. How do the results from one question help you solve the next?

4.2) Implementation

Now it's time to implement your *Hypermines* game! You should do so by filling in the skeletons of the `new_game_nd`, `dig_nd`, and `render_nd` functions in `lab.py`.

One of the implementation challenges in *HyperMines* is arbitrary-depth iteration. We include a few hints that you may find useful as you think about which recursive helper functions would be helpful in dealing with N-dimensional arrays represented as nested lists, and the questions above may also be helpful.

Note also that, because of the size of some of these test cases, you may need to be a little bit careful about efficiency, as well.

4.3) How to test your code

We provide three scripts to test and enjoy your code:

- `python3 lab.py` will run the doctests presented in the file.
- `python3 test.py` runs all the tests used for grading, as well as any additional test cases you put in `test.py`
- `python3 server_nd.py` lets you play *HyperMines* in your browser! The server uses your code to compute consecutive game states and to render the results.

5) Refactoring Again

After having implemented *HyperMines*, you may notice that we now have a new opportunity to re-organize some of our two-dimensional code to take advantage of the (more general) code we have written for the N-dimensional game. Try to reorganize your code for the 2-D game, where possible, to make use of these new structures (but make sure that it continues to function as expected!).

6) Code Submission

After you have tested locally, submit your **`lab.py`** in the box below:

Download Your Last Submission
Click to View Your Last Submission
Click to Show All Submissions
Select File No file selected

Submit

You have submitted this assignment 6 times.

This question is due on Friday March 06, 2020 at 04:00:00 PM.

7) Checkoff

Once you are finished with the code, please come to a tutorial, lab session, or office hour and add yourself to the queue asking for a checkoff. **You must be ready to discuss your code and test cases in detail before asking for a checkoff.**

You should be prepared to demonstrate your code (which should be well-commented, should avoid repetition, and should make good use of helper functions). In particular, be prepared to discuss:

- Your implementation of `render_2d` and `render_ascii`
- The changes you made to refactor `new_game_2d` and `dig_2d`, as well as the issues that your refactoring fixed compared to the original code
- Your implementation of `new_game_nd`, including any helper functions.
- Your implementation of `dig_nd`, including any helper functions.
- Your implementation of `render_nd`, including any helper functions.
- Any new doctests (or test cases in `test.py`) that you added.

7.1) Grade

You have not yet received this checkoff. When you have completed this checkoff, you will see a grade here.