02-201 Extra Credit Homework: Sandpiles

Extra Credit Due: 11:59pm on Monday, November 16

1. Set up

The set up is the basically the same as for previous homeworks.

1. Create a directory called "`go`" someplace (different than where you have installed Go) [If you've already done this, you don't have to do it again.]
2. Inside of that directory create a directory called `src` [If you've already done this for a previous assignment, you don't have to do it again.]
3. Inside of the `src` directory, create a directory called `sandpile`.
4. Download the template `canvas.go` from Piazza (or copy it from a previous assignment) and put it into the `sandpile` directory. Also copy over the `code.google.com` directory from a previous assignment if it isn't already in your `src` directory.
5. Set your GOPATH environment variable to the location of your `go` directory that you made above. On a Mac:

   ```
   export GOPATH=/Users/carlk/Desktop/go
   ```

   where you replace the directory name after the `=` with the location of the `go` directory you just made.

   On Windows use

   ```
   set GOPATH=C:\Users\carlk\Desktop\go
   ```

2. Assignment

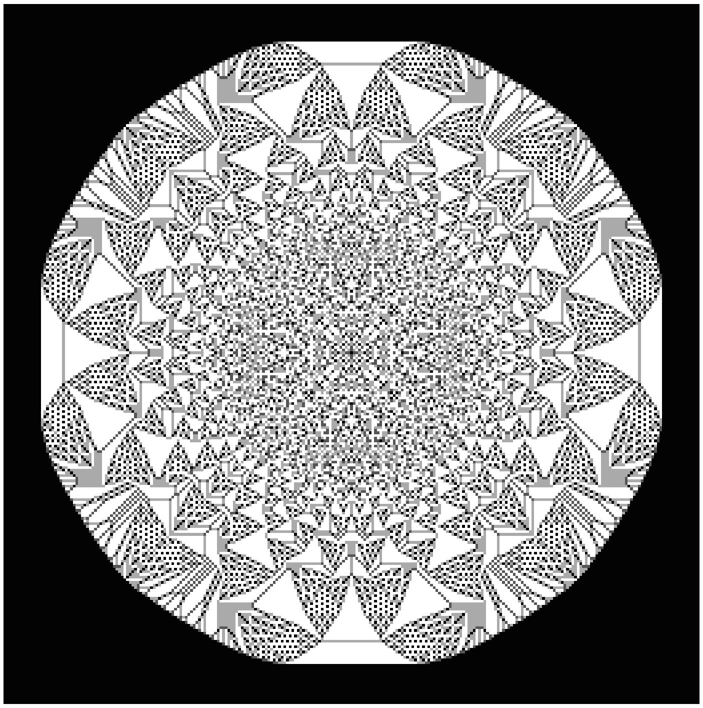
2.1 Sandpiles

Imagine an infinite 2-D checkerboard on which you place piles of coins of various heights on some of the squares (at most 1 pile per square). Consider the following toppling operation:

> topple(r, c): if square (r, c) has ≥ 4 coins on it, move 1 coin from (r, c) to each of the 4 neighbors of (r, c) (diagonal neighbors don't count, only north, south, east, and west).
> If square (r, c) has < 4 coins, do nothing.

A configuration of coins is said to be *stable* if all squares have < 4 coins on them. If we repeatedly topple until we can't topple any more, we'll end up at a stable configuration. Somewhat surprisingly, you can show than the order of the topples that you do won't affect the final stable configuration that you end up in, given a particular starting point.

For example, if you start with a pile of 100000 coins on a single square, and no coins elsewhere, you will end up with the following configuration:



where the color indicates the number of coins (0=black, 3=white, and 1 and 2 are intermediate shades of gray).

You can read more about these here:

`http://www.cmu.edu/homepage/computing/2014/fall/lifes-a-beach.shtml`

2.2 What you should do

Write a program that can be run with the following command line:

```
sandpile SIZE PILE
```

where `SIZE` and `PILE` are both positive integers. `SIZE` gives the size of checkerboard which will be $\texttt{SIZE} \times \texttt{SIZE}$. `PILE` gives the number of coins that are to be placed on the middle square at position $(\lfloor \texttt{SIZE}/2 \rfloor, \lfloor \texttt{SIZE}/2 \rfloor)$ at the start.

This program should find the stable configuration associated with the given initial configuration. It should then draw the final board in a PNG file called `board.png`. The colors corresponding to each number of coins should be, given in (Red, Green, Blue) values:

0	(0,0,0)
1	(85,85,85)
2	(170, 170, 170)
3	(255, 255, 255)

Each board square should be drawn as a 1 × 1 square.

Your program must create a new type called `Board`, with the following methods:

- `Topple(r, c int)` that topples (r, c) until it can't be toppled any more.

- `Contains(r,c int) bool` that returns true if (r, c) is within the field.
- `Set(r,c, value int)` that sets the value of cell (r, c).
- `Cell(r, c int) int` that returns the value of the cell (r, c).
- `IsConverged() bool` that returns true if there are no cells with ≥ 4 coins on them.
- `NumRows() int` that returns the number of rows on the board.
- `NumCols() int` that returns the number of columns on the board.

Speed. Your program should be fast enough to run `./sandpile 2000 10000` in at most a few seconds. It should be able to run `./sandpile 2000 100000` in about 15 minutes (give or take a factor of 2 depending on your computer speed).

Coins can fall off the edge of the board, in which case they are lost forever.

2.3 Tips on how to start

First, write the code for the `Board` functions.

Then, write the code to parse the command line, and a function `CreateBoard` that returns a new board with the right dimensions and the initial configuration.

Next, write `ComputeSteadyState(b *Board) int` that topples squares until the board has converged to a stable configuration.

Finally, write a `DrawBoard` function that draws the board to a PNG.

Between each of those steps, you should make sure your program complies.

3. Learning outcomes

After completing this homework, you should have

- gotten more experience with an "object-oriented" way of thinking
- learned about sandpiles
- worked on making a program faster if needed