Assignment 1: The Game Of Life

A brilliant assignment from Julie Zelenski.

Let the fun begin! Your first real assignment centers on the use of a two-dimensional grid as a data structure in a cellular simulation. It will give you practice with control structures, functions, templates, and even a bit of string and file processing. More importantly, the program will exercise your ability to decompose a large problem into manageable bits. What’s especially nice about this program is that you can construct a beautiful and elegant solution if you take the time to think through a good design. It can be as lovely to look at the code as it is to watch it run.

Checkpoint Due: Wednesday, October 3rd at 3:00 p.m.
Full Project Due: Friday, October 5th at 3:00 p.m.

The Problem

Your mission is to implement a hyped-up version of the game of Life, originally conceived by the British mathematician J.H. Conway in 1970 and popularized by Martin Gardner in his Scientific American column. The game is a simulation that models the life cycle of bacteria. Given an initial pattern, the game simulates the birth and death of future generations using simple rules. Think of it as a Lava Lamp for mathematicians.

The game is played on a two-dimensional grid. Each grid location is either empty or occupied by a single cell (X). A location’s neighbors are any cells in the surrounding eight adjacent locations. In the following example, the shaded middle location has three "live" neighbors:
The Checkpoint
This assignment is likely bigger and more complicated than anything you built during your time in CS106A or AP Java. To ensure that you’re not blindsided by the sheer amount of work, we’re asking that you submit a partially working program—one that implements much of the program flow—two full days before the formal due date.

For the Wednesday checkpoint, you should submit a partially working program that:

- prints out all of the text that gets printed to the console, as illustrated by the sample application,
- prompts the user to either generate a random grid, or to initialize a grid based on the contents of a data file,
- populates a grid using either randomization or by reading in the contents of the named file, and
- draws the initial state of the grid to the graphics window, waiting for a mouse click to clear the screen and start over.

In a nutshell, the checkpoint implements the setup and all of the plumbing for the game of Life, without playing the actual game.

We won’t be assigning a formal grade to the checkpoint submission, but your section leader—even if you haven’t met him or her by the time you submit—will email you if he or she finds any major no-nos. We’re strongly recommending that you submit this by Wednesday at 3:00 p.m. so that you gain a sense of the program’s complexity sooner and not later. Should you find yourself struggling with the checkpoint requirements, we can schedule an intervention more than a day in advance of the deadline.

The Rules
The simulation starts with an initial pattern of cells on the grid and computes successive generations of cells according to the following rules:

1. A location that has zero or one neighbors will be empty in the next generation. If a cell was in that location, it dies of loneliness.
2. A location with two neighbors is stable—that is, if it contained a cell, it still contains a cell. If it was empty, it's still empty.
3. A location with three neighbors will contain a cell in the next generation. If it was unoccupied before, a new cell is born. If it currently contains a cell, the cell remains. Good times.
4. A location with four or more neighbors will be empty in the next generation. If there was a cell in that location, it dies of overcrowding.
5. The births and deaths that transform one generation to the next must all take effect simultaneously. Thus, when computing a new generation, new births and deaths in that generation don’t impact other births and deaths in that generation. To keep the two generations separate, you will need to work on two versions of
the grid—one for the current generation, and a second that allows you to compute and store the next generation without changing the current one.

Check your understanding of these rules with the following example. The two patterns below should alternate forever:

```
X X X
```

```
X
X
X
```

**The Starting Configuration**

To get the colony underway, your program should offer the user a chance to seed the grid randomly or read in a colony configuration file. If the user requests a random start, use the functions in the random number library ("random.h") to choose arbitrary cells to be alive (each with a 50% chance of being alive), and just go with a reasonably large number of rows and columns (the sample application sets each dimension to be between 40 and 60, inclusive). If the user instead wants to start with a known configuration, you read the starting colony from a text file.

```
# Any line that begins with a #
# is a comment and is ignored
30
25
-----xxxx-----xxxx-----
-------xxxx-------
-------xxxx-----xxxx-----
      ... and so on ...
```

You can read the file line-by-line using the standard `getline` method (note that this is distinct from the CS106-specific `getLine` that just reads from the console). All colony files obey the above format, and you may assume that the files are properly formatted (i.e. it is not required that you do error checking).

**Managing the Grid**

Basically what's needed for storing the grid is a two-dimensional array. However, the built-in C++ array is fairly primitive. C arrays (and thus C++ arrays) are long on efficiency but low on safety and convenience. They don't track their own length, they don't check bounds, and they require messing with pointers and dynamic memory and so on. We're taking a more modern approach—that of using a Grid class that provides the abstraction of a two-dimensional array in a safe, encapsulated form with various conveniences for the
client. Just as the Vector provides a cleaner and less error-prone abstraction for a one-
dimension array, the Grid offers the same upgrade for two-dimensional needs. These
classes, among others, are from the CS106 tool set that we will be using throughout the
quarter. Refer to Handout 06’s Queen Safety examples if you want to see the Grid in
action.

Your grid should store an integer for each location rather than a simple alive-or-dead
Boolean value. This allows you to track the age of each cell. Each generation that a cell
lives through adds another year to its age. A cell that has just been born has age 1. If it
makes it through the next generation, that cell has age 2, on the following iteration it would
be 3 and so on. During the animation, cells will fade to light gray as they age to depict the
cell life cycle.

As mentioned earlier, you will need two grids: one for the current generation and a
separate scratch grid to set up the next generation without interfering with the current one.
After you have computed the entire next generation, you can copy the scratch grid contents
into the current grid to get ready for the next iteration. Copying a grid is trivial—just assign
one grid to another using =. The Grid class implements the regular assignment operator to
do a full, deep copy.

**Animating the World**

We provide the life-graphics.h module that exports a LifeDisplay class to help
you draw the cells in a dedicated window. Our cell-drawing methods will slowly fade
cells as they age. A newly born cell is drawn as a dark dot and with each generation the
cell will slightly fade until it stabilizes as a faint gray cell. See the life-graphics.h
interface in the starter files for details on the specifics of the methods we provide and how
to use them.

The graphic window module (#include "gwindow.h") exports a function called pause
to stall execution a bit in order to allow you to see what happened before proceeding. You
should offer the user a couple of options for simulation speed; this will translate to shorter
or longer pauses between generations. We also want you to support a manual mode
where the user has to explicitly hit return to advance to the next generation. This mode is
particularly handy when you are first learning how the rules operate or need to do some
careful debugging.

You should continue computing and drawing successive generations until the colony
becomes completely stable or the user clicks the mouse button. If the colony has evolved
to a configuration that has no changes between generations (other than live cells
continuing to age) and all cells hit or exceed the constant MaxAge (defined
in "life-constants.h") you should end the simulation. Colonies that infinitely repeat
or alternate are not considered stable and thus the user will need to click to end those.
When a simulation ends, you should then offer the user a chance to start a new simulation
or quit the program entirely.
**Program Strategies**

A high-quality solution to this program will take time. It is not recommended that you wait until the night before to hack something together. It is worthwhile to map out a strategy before starting to code. Amazingly concise and elegant solutions can be constructed — aim to make sure yours is one of them!

**Decomposition:** This program is an important exercise in learning how to put decomposition to work. Decomposition is not just some frosting to spread on the cake when it's all over—it's the tool that helps you get the job done. With the right decomposition, this program is much easier to write, to test, to debug, and to document! With the wrong decomposition, all of the above will be a chore.

You want to design your functions to be of small, manageable size and of sufficient generality to do the different flavors of tasks needed. Strive to unify all the common code paths. A good decomposition will allow you to isolate the details for all tricky parts into just a few functions.

Avoid special cases, don't handle inner cells, edge cells, and corner cells differently—write general code that works for all cases. No special cases means no special-case code to debug! Think carefully about how to design these functions to be sufficiently general for all use cases.

**Incremental Development and Testing:** Don't try to solve it the entire task at once. Even though you should have a full design from the beginning, when you're ready to implement, focus on implementing features one at a time. Start off by writing code to meet the checkpoint requirements. Continue by seeding your grid with a known configuration to make it easier to verify the correctness of your simulation. Initialize your grid to be mostly empty with a horizontal bar of three cells in the middle. When you run your simulation on this, you should get the alternating bar figure on page 3 that repeatedly inverts between the two patterns. It's easiest to get your program working on such a simple case first. Then you move on to more complicated colonies, until it all works perfectly.

Avoid the "extra-layer-around-the-grid": At first glance, some students find it desirable to add a layer around the grid—an extra row and column of imaginary cells surrounding the grid. There is some appeal in forcing all cells to have exactly eight neighbors by adding "dummy" neighbors and setting up these neighbors to always be empty. However, in the long run this approach introduces more problems than it solves and leads to confusing and inelegant code. Before you waste time on it, let us tell you up front that this is a poor tradeoff and a strategy to avoid. Just assume that locations off the grid are empty and can never count as neighbors.
Other Random Notes and Hints

• Error checking is an important part of handling user input. Where you prompt the user for input, such as asking for file to open, you should validate that the response is reasonable and if not, ask for another. (You can assume that the data files themselves are well formed, though.)

• While developing, it’s helpful to circumvent the code that prompts for the configuration and just force your simulation to always open "Simple Bar", a random colony, or whatever you are currently working on. This will save you from having to answer all the prompts each time when you do a test run.

• Although you might be tempted, you should not use any global variables for this assignment. Global variables can be convenient but they have a lot of drawbacks. In this class we will never use them. You should always assume that global variables are forbidden unless we explicitly tell you otherwise. (Global constants are fine, though.)

• Note that all of the data files reside in a directory called "files". When opening a data file name "Fish", you need to prepend "files/" to the front of it, else the ifstream constructor won’t be able to find it.

• Allowing the game to animate while constantly polling for mouse clicks is a tricky thing. Look at the "gevents.h" file documentation via the course website (look for the CS106B Library Documentation link) to see how one can poll for mouse events without blocking. I don’t want you to invest too much energy into mouse events, so I’m presenting my own approach to non-blocking mouse event detection right here.

```cpp
void runSimulation(LifeDisplay& display, Grid<int>& board) {
    while (true) {
        GMouseEvent me;
        if (getNextEvent(me)) {
            if (me eventType() == MOUSE_CLicked) return;
        } else {
            // only advance board if there aren’t any outstanding mouse events
            advanceBoard(display, board);
        }
    }
}
```

You should cannibalize the code snippet above and extend it as necessary as you fold it into your own solution. Focus on how the getNextEvent function works by reading the documentation about that function in particular. You should avoid the non-mouse event types, as the libraries aren’t fully implemented yet, and in particular, GKeyEvents and GTimerEvents aren’t working yet (though Eric Roberts hopes to implement all event types very shortly.)

Coding Standards, Commenting, Style

This program has quite a bit of substance, however, the coding complexity doesn't release you from also living up to our style standards. Carefully read over the style information we
have given you and keep those goals in mind. Aim for consistency. Be conscious of the
style you are developing. Proofread. Comment thoughtfully.

Test Colonies
We have concocted several colony configuration files for you to use as test cases. There is
also a compiled version of our solution, so that you can see what the correct evolutionary
patterns should be. Some of our provided colonies evolve with interesting kaleidoscopic
regularity; a few are completely stable from the get-go, and others eventually settle into a
completely stable or infinite repetition or alternation. Each file has a comment at the top of
the file that identifies the contributor and tells a bit of what to expect from the colony.

We'd love additional colony contributions, so if you create a beautiful bacteria ballet of
your own, please send it to us and we can share it with the class.

Getting Started
Follow the Assignments link on the class web site to find the starter bundle for
Assignment 1. You should download this file to your own computer and open the bundle.
For this assignment, the bundle contains some custom header files, our life-
graphics.cpp implementation, and an incomplete version of life.cpp.

Deliverables
For the checkpoint, you can either electronically submit your changes to life.cpp, or
you can just cut and paste your code into an email that you send to your section leader.
You won’t know who your section leader is until Monday morning, but that still gives you
a whole two days to send an email. You can do that. 😊

For the final submission, you only need to electronically submit those files that you
modified, which in this case, will probably just be life.cpp. There are instructions on
the course web site outlining how to electronically submit (look for the Submitter link on
the course web page). You are responsible for keeping a safe copy to ensure that there is a
backup in case your submission is lost or the electronic submission is corrupted.