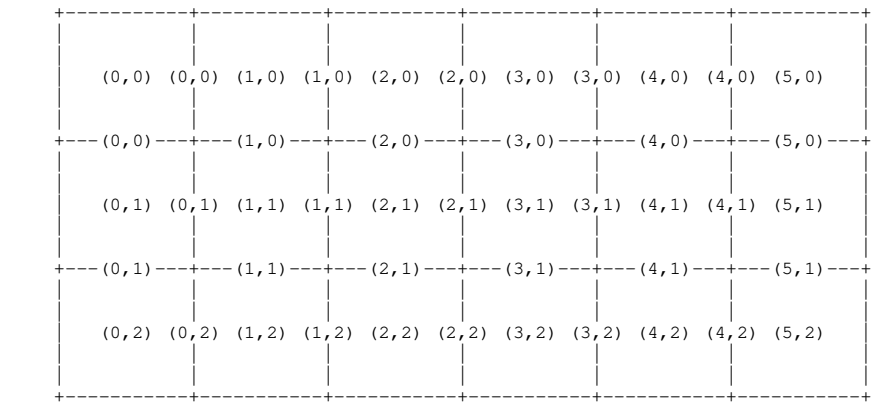
CS 61B Homework 9
Due 3pm Wednesday, April 19, 2000

Part I (8 points)

Edit the file Maze.java and complete the implementation of the Maze constructor. Use our disjoint sets data structure to create a random rectangular maze. Your random mazes should have two properties: there is a path from any given cell to any other cell, and there are no cycles (loops)-- in other words, there is only one path from any given cell to any other cell.

Each maze is an h-by-v grid of square cells (where h is the number of cells in the horizontal direction, and v is the number of cells in the vertical direction). The cell in the upper left corner is numbered (0, 0). The cell to its right is numbered (1, 0). The cell below the upper left cell is numbered (0, 1).

There are vertical walls and horizontal walls separating adjacent cells. Each interior horizontal wall has the same numbering as the cell immediately above it. Each interior vertical wall has the same numbering as the cell to its immediate left. Hence, horizontal wall (i, j) separates cell (i, j) from cell (i, j + 1), and vertical wall (i, j) separates cell (i, j) from cell (i + 1, j). Here is a depiction of a 6-by-3 grid.



Note that there is an h-by-(v-1) set of horizontal walls, and an (h-1)-by-v set of vertical walls. In your maze, some of these walls will be present and some will be missing. The walls present are indicated by the arrays hWalls and vWalls, which are an h-by-(v-1) boolean array and an (h-1)-by-v boolean array, respectively. (Exterior walls are numbered according to the same system, but there is no explicit storage for them, because they are presumed to always be present.)

The Maze constructor currently creates a "maze" in which every possible wall is present. To make a proper maze, you will need to eliminate walls selectively. Do so as follows.

(1) Create a disjoint sets data structure in which each cell of the maze is represented as a separate item. Use the DisjointSets class (described in the Lecture 34 notes), which is in the set package.
(2) Visit every interior wall of the maze (once) in a random order.

    One way to do this is to create an array in which every wall (horizontal and vertical) is represented. (How you represent each wall is up to you.) Maintain a counter w, initially set to the number of walls. Iterate the following procedure: select one of the first w walls in the array at random, and swap it with the wth wall in the array. (This has the effect of choosing a random wall to fill the wth place in the array.) Then decrease w by one. Repeat this operation w times, so that each element of the array, starting with the last, references a random wall.

    Next, visit the walls in random order. For each wall you visit:

    (i) Determine which cell is on each side of the wall.
    (ii) Determine whether these two cells are members of the same set in the disjoint sets data structure. If they are, then there is already a path between them, so you must leave the wall intact to avoid creating a cycle.
    (iii) If the cells are members of different sets, eliminate the wall separating them (thereby creating a path from any cell in one set to any cell in the other) by setting the appropriate element of hWalls or vWalls to false. Form the union of the two sets in the disjoint sets data structure.

When you have visited every wall once, you have a finished maze!

Be forewarned that the DisjointSets class has no error checking, and will fail catastrophically if you union() vertices that are not roots of their respective sets, or if you union() a set with itself. You may want to add error checking to DisjointSets.java to help you find your bugs. This error checking can help you with Project 3 as well.

All the other methods you need, including test methods, are provided for you.

  toString() converts the maze to a string so you can print it.
  randInt(c) generates a random number from 0 to c - 1, and is provided to help you write the Maze() constructor. For fun, it generates a different sequence of random numbers each time you run the program.
  diagnose() tests your maze for cycles or unreachable cells using depth-first search. DON'T CHANGE IT. YOUR CODE MUST WORK WITH _OUR_ COPY OF THIS METHOD.
  main() generates a maze, prints it, and tests it.

diagnose() depends on the following two methods, so don't make changes that will prevent these from working:

  horizontalWall(x, y) determines whether a horizontal wall is intact.
  verticalWall(x, y) determines whether a vertical wall is intact.

You may see how you're doing by compiling and running Maze.java. To look at a 30 x 10 maze, run:

  java Maze 30 10

The default dimensions, if you don't specify any on the command line, are 39 x 15.

Part II (2 points)

The diagnose() method uses depth-first search to test your maze. Think of the cells of the maze as vertices of a graph. Two adjacent cells are connected by an edge if there is no wall separating them.

If the depthFirstSearch() method ever examines an "edge" and discovers a cell that has already been visited, then there is a cycle in the maze. (The depth-first search implementation used here never walks back over an edge it's just traversed, so it won't look back and mistakenly diagnose a cycle.) If some cell is not visited at all, then it is not reachable from the cell where the search started. Hence, depth-first search can diagnose both potential deficiencies of a bad maze: having more than one path between two cells, or having no path between two cells. (You may want to look at the diagnose() and depthFirstSearch() methods to see how this is done.)

In a file named GRADER, suggest (in simple English) how you could use depth-first search to generate a random maze (or more importantly, lots of different random mazes), without using disjoint sets at all.

(a) How would your algorithm ensure that there is a path between every pair of cells, but no more than one path between any pair of cells (i.e., no cycles)?

(b) How does your algorithm use random numbers to generate a different maze each time? Specifically, what decision should be made by random numbers at each recursive invocation of the depth-first search method?

These questions can be answered with just a few sentences.

Submitting your solution

Change (cd) to your hw9 directory, which should contain GRADER, Maze.java, any other files your solution needs, and the set directory. The set directory should contain DisjointSets.java. You must submit the latter because you're allowed to change it. Include your name, login, and lab section in GRADER. From your hw9 directory, type "submit hw9".