

Programming Project 6

EE312 Fall 2021

General: This project will give you a chance to write some recursive functions.
PLEASE NOTE: Your recursive functions must not use loops and must not use global variables!

Your Mission: Edit the file Project6.cpp. This project consists of five parts. For each part you should write both a recursive function and an iterative function to solve the problem (i.e., you'll write a total of eight functions for this project). Each of the projects is independent, and they're all very short. **NOTE: We will only grade the recursive version of each problem, so if you'd like, you can skip the iterative versions. For both part 4 and part 5, the iterative version is challenging.**

Part 1: Write three functions to find the smallest element in a set. The first function, *minIt*, should use a loop (i.e., be an iterative solution). The second function *minRec1* should be a recursive function that uses a decomposition where the size of the smaller problem is $n-1$ (where n is the size of the original problem). The third function, *minRec2* should be a recursive function that uses a decomposition where the size of the smaller problem is $n/2$. Note that your recursive functions will not have any loops!

Part 2: Write two functions to calculate the square root of a number. The first function, *squareIt* should be iterative and the second function *squareRec* should be recursive. You'll be using floating point numbers (type **double**) for this question, so it is impossible to calculate the square root exactly. Instead you must calculate the square root accurate to 15 (decimal) significant digits. Your functions will use three parameters. The first parameter is the value for which you must calculate the square root. The other two parameters are "guesses". The first guess is guaranteed to be smaller than the actual square root. The second guess is guaranteed to be larger than the actual square root. These parameters should give you a big hint how to solve this problem.

Part 3: Write two functions to perform string comparison. Both functions must use only recursion (no loops or global variables). In the first function, write the conventional `strcmp` function, which compares characters using their ASCII values. The comparison is case sensitive, and punctuation is significant. So, for example, " zzz" is less than "aaa" because the former string has a space in front (ASCII 32) which is less than the ASCII for 'a'. Follow the conventions for `strcmp`, return -1 if the first string is less than the second, return 0 if the strings are the same and return 1 if the first string is greater than the second. Call your function `strCompare` (it's already declared for you in the project file).

Once you've finished writing the traditional `strcmp` function (using only recursion!) write a new version of the function that compares only the letters in the strings and ignores the case (upper/lower case) of the letters. For this version, " ZZZ" is greater than "aaa" since

the space is ignored and the capitalization is also ignored. Similarly, the two strings “C++ programming” and “c programming” are equal to each other. Name this function `strCompare2` (it’s also already declared for you in the project file).

Part 4: Write two functions to find the solution to a maze. The maze is represented by a two-dimensional matrix. The syntax for accessing an element of the matrix is `maze[row][col]` where *row* and *col* are the row number and column number for a cell in the matrix. If the value of an element in the matrix is 1, then the corresponding square in the matrix is a wall, and you cannot go into that square. If the value of the element is 0, then you can go into the square. The entrance to the maze is a square in row 0 and the exit is a square in the last row (`MATRIX_SIZE - 1`). The maze is square with `MATRIX_SIZE` rows and `MATRIX_SIZE` columns.

The maze is generated with some special properties that make finding a solution relatively easy. There is exactly one path between any two squares in the maze (except walls of course, there are no paths that allow you to walk into a wall). To look at the maze that’s generated, call the *printMaze* function and you’ll see what I mean. This means that there are no loops or circular paths in the maze.

For the iterative solution to the maze problem, you’ll rely on this property. The algorithm you’ll use is “follow the right hand wall”. The image you should have is that of a blind person trying to get out of the maze. By sticking out their right arm and keeping their right hand along a wall, they’ll eventually get out of the maze. To code this algorithm in C, you’ll need to keep track of where you currently are in the maze, and what direction you are currently heading. I’ve written a few functions to help you “move” through the maze. The functions *turnRight* and *turnLeft* assume that you’re using an integer to keep track of your direction. The four directions are 0 for up (rows get smaller, columns stay the same) 1 for moving right (the row stays the same, but the column increases), 2 for moving down (the row increases, the column stays the same) and 3 for moving left (the row stays the same and the column decreases). The function *adjacentCell* calculates the correct row and column for one of the four adjacent cells to your current position. Note that you are not allowed to move diagonally, only one of the four directions.

Anyway, the basic technique is to keep walking through the maze with your right hand on the wall until you get to the last row of the maze at which point you should stop (you’ve found the exit). To prove that you’ve found your path through the maze, you should leave a trail of “bread crumbs” on the path. For full credit, your bread crumbs should only be left along the correct path to the exit (this is not as hard as it might sound – the maze is designed to ensure that there’s only one path to the exit that does not involve backtracking). To indicate a bread crumb, you should set the element in the matrix equal to 2. When you run *printMaze* any of the squares with bread crumbs will be displayed as the letter “o”.

For the recursive solution to the problem you’ll write a much more general maze solver. Unlike the iterative version, there’s a fairly straightforward recursive solution to mazes that will work with any type of maze (recall for this problem we’re generating a special

maze so that the “follow the right hand wall” will work), but since our mazes are special, we can write a slightly simpler version than the general version that relies on the fact that you cannot go round in circles.

In any event, for the recursive solution you’ll drop a bread crumb in the current square and then check to see if any of your adjacent squares are on a path to the exit by making up to 4 recursive calls, one by one. One of the adjacent squares you encounter will of course have a breadcrumb (the one you came from), and you are not going to go back to that square (yet). If all of the other adjacent squares are walls, then this square is clearly not on the correct path to the exit. So you pick up the breadcrumb that you dropped and return 0. Returning 0 will take you back to the square from which you came, from where you will try the next direction, if any exists, to the exit.

If you reach the exit, you don’t pick up the breadcrumb, but simply return 1. What will be left behind are the breadcrumbs that lead to the exit.

There’s a bit more detailed hint in the comments in *Project6.cpp*.

Please note the maze is much more challenging than the first three. The iterative version is interesting, but will not be graded.

Part 5: Write a function that makes change. The input to the function is the amount of money (cents). The return value from the function must be a struct where the components indicate the number of coins which will add up to the amount of money. For this problem, we’ll use a fictitious currency (Martian currency) which has 1-cent, 5-cent and 12-cent coins (pennies, nicks and dodeks). To receive credit, your function must use the minimum number of coins possible. For example, if the input to the function were 15, then you should return a Martian struct with the dodek and pennies components both set to zero and the nicks component set to 3 (since three nicks is the most efficient way to create 15 cents using martian currency). If the input were 17, then you should return a Martian struct with pennies equal to zero, nicks equal to 1 and dodeks equal to 1.

The real version of this problem is one where the value of each of the coins is not known in advance. i.e., you know there are three coins, and one of the coins (the penny) is worth 1 cent. However all you know about the other coins is that the nick is worth a cents, the dodek is worth b cents, and $1 < a < b$ for some integers a and b . Clearly, if you can solve this version of the problem, then you can solve the specific case where $a = 5$ and $b = 12$ (described above). Both versions of the problem are included in *Project6.cpp* for you to complete.

CHECKLIST – Did you remember to:

- ☐ Re-read the requirements after you finished your program to ensure that you meet all of them?
- ☐ Make sure that your program passes all our testcases?
- ☐ Make up your own testcases?
- ☐ Upload your solution to Canvas?
- ☐ Download your uploaded solution into a fresh directory and re-run all testcases?

FAQ

Q: I am getting Warnings about deprecated functions on mario.
A: Type 'module load gcc' after logging in to mario, before typing make. See Piazza also for further details.

Q: Can we use globals or static variables? How about helper functions?

A: You can't use your own globals or statics, but you can use helper functions as long as they don't have loops, globals, or statics.

Q: Are we allowed to modify the whatLetter function in our starter code?

A: No, but you can write your own different function.

Q: Does the sqrt function need to work for values less than 1 and negative values?

A: It should work for values less than 1, but you can assume you won't get negative values.

Q: What should the min function return if the array length is 0?

A: The minimum isn't well defined there, so we will not give you a case where the array length is 0.

Q: Do we have to do anything with the iterative functions? Can we delete them?

A: You don't have to fill them in, but you shouldn't delete them. Just leave them blank if you don't want to do them.

Q: How can I test my maze function with more mazes?

A: Seed the random number generator used to make the maze. Right before the makeMaze function in main, there is a call to srand that passes in a number. Changing that number will create a different maze to test with.

Q: For the makeChange function, if there are multiple ways to use the fewest number of coins, which one do we choose?

A: It doesn't matter, choose any of them.

Q: Do we put a 'o' at the start and end of the maze too?

A: Yes, both start and end.

Q: What is the maximum amount of money that will be tested for makeChange?

A: After 50 or so, the function gets pretty slow because we are using almost a brute force algorithm. We will not test higher than that.

Q: How do I check the accuracy of my square root?
Since doubles have about 15-16 decimal digits of accuracy, the program is doable with doubles. You may divide the difference between low_guess and high_guess by their average, and it should be $\leq 10^{-15}$. For example, if the guesses are 8.0001 and 8.0002, the number we get is $0.0001/8$, which is < 0.00001 , which is $< 10^{-5}$. So we conclude that the number 8.0001 is accurate to 5 decimal digits.