Graded Lab 3: Recursion vs Iteration

Objective

Evaluate the strengths and weaknesses of recursive algorithms in relation to the time taken to complete the program, and compare them to their iterative counterparts.

Introduction

Recursion can be difficult to grasp, but it emphasizes many very important aspects of programming, including execution speed and complexity. For this lab, you will program two well-known problems in their iterative and recursive forms: the Fibonacci number and the sum_N_odds problem.

Task 1 – Write code for the following functions.

a. Code the following functions for a Fibonacci number (fib) using these prototypes:

```
int iterativeFibonacci(int n);
int recursiveFibonacci(int n);
```

Fibonacci number (fib) is defined as the sum of the previous 2 numbers in its sequence, given that fib (1) = 1 and fib (2) = 1.

fib (n) = fib (n-1) + fib (n-2)

For example, fib (3) = fib (2) + fib (1) = 1 + 1 = 2. Similarly, fib (4) = fib (3) + fib (2) = 2 + 1 = 3.

b. Code the following functions for sum_N_odd numbers using these prototypes:

```
int iterativeSumNOdd(int n);
int recursiveSumNOdd(int n);
```

Sum of n odd numbers = 1 + 3 + 5 +…+ n

For example, sumNOdd (3) = 1 + 3 + 5 = 9. Similarly, sumNOdd (5) = 1 + 3 + 5 + 7 + 9 = 25.

Each of these 4 functions should be contained in its own function file, named to match the name of the function inside. (Ex. the iterative Fibonacci function will be in *iterativeFibonacci.c*). Each of these will be linked to a main.c with the following specification:

1. The main will take a single command line input (an integer value) from the user and store it in '*n*'.
2. The main will then run each of the four functions in sequential order, keeping track of the time that is taken for each function to run to completion. You will find a sample code using the time functions you may find useful for this lab.
3. The main will then output the runtime for each function.

Output

Output will be formatted as four lines, following this specified format:

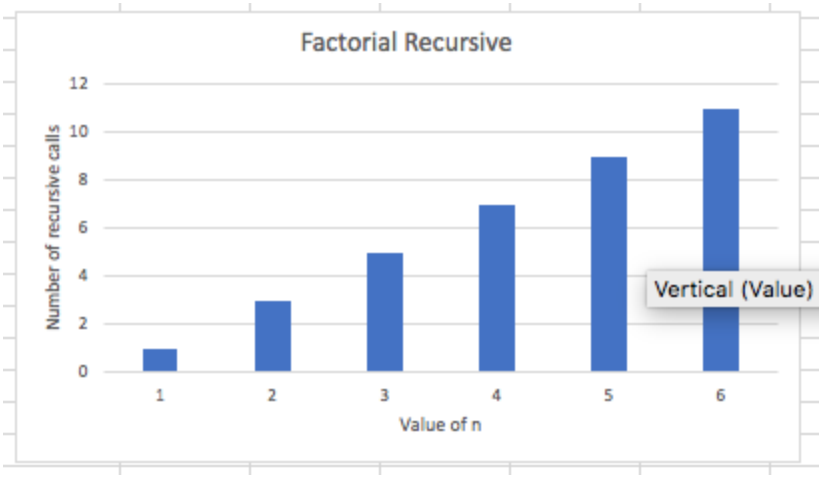
Time to complete iterative Fibonacci of size *n*: XX.XX seconds.
Time to complete recursive Fibonacci of size *n*: XX.XX seconds.
Time to complete iterative Sum_N_Odd of size *n*: XX.XX seconds.
Time to complete recursive Sum_N_Odd of size *n*: XX.XX seconds.

No other output will be displayed; however, it is advised that you include additional print statements while testing to ensure that the correct answer is being calculated.

Also note that the displayed time to complete may be different at different times and different on different machines. That happens because the time that a program takes to execute depends on the load that the machine has in that specific moment – so it is normal for it to vary. But it meets the purpose of this lab as it allows us to compare iterative and recursive functions – note that we are not interested in computing the exact time for these functions.

Task 2

You are required to plot 2 graphs for the **2 recursive functions**. You may use Excel or any other tool to plot the graphs. The graph must show the relationship between n and the number of recursive calls made for n. A sample graph is shown for the recursive factorial function discussed in class.



Submission

a. Submit your finished code to the lab 3 repository on GitLab. Include a makefile to link the four function files to the main and output an executable named "lab3". The makefile must also include a 'clean' option, which removes all executables and (if present) intermediate .o files. All compilation should be done with the -Wall and -std=c99 flags.

b. Submit the file with graphs on Gitlab lab 3 repository as a pdf file.

Grading

Grading will be based on i) the number of successfully generated functions (four algorithm functions plus a working and linked main function), proper submission instructions, and correct execution of the program. Serious code style offences will be incur a small penalty to the final grade for this submission. Warnings may be penalized, and submissions that do not compile will be given a zero.

Tips

- Start with the iterative functions, as they are lengthier and more laborious to complete. More importantly, they'll provide expert knowledge about the algorithm that you'll need to understand the recursive versions.
- The recursive functions, by design are short and succinct. If your recursive functions start to go beyond 50 lines to complete, reconsider your algorithm: there might be a much simpler program that you can build.
- The main function is simple, but will require you to learn about how to time things in seconds and milliseconds. Standard library #include time.h has the functions you're looking for. **Page 3 has a sample code that you may use.**
- If you're not seeing a major difference in timings between the functions, try scaling up your program to use larger values of *n*. Some good numbers to try when scaling up might be 5, 10, 25. If you get up to these values and still don't see a difference, there might be something wrong with your implementation.

Sample code using clock () and time.h

Below is given a code that finds the clock time of a code that runs a for loop 1000000 times. As can be seen in the sample run, values of elapsed time are different for each run. That happens because the time that this program took to execute depends on the load that the machine has in that specific moment – so it is normal for it to vary. But it meets the purpose of this lab as it allows us to compare iterative and recursive functions – note that we are not interested in computing the exact time for these functions.

~/Documents/GUELPH/Teaching2019_W2021/Winter2021/CIS2500_W21/Winter2021/Labs/Lab3/sampleProgramTime.c

```c
#include <stdio.h>
#include <time.h>       // for clock_t, clock(), CLOCKS_PER_SEC

// main function to find the execution time of a C program
int main()
{
    double timeElapsed = 0.0;

    clock_t begin, end;

    begin = clock();

    for (int i = 0; i < 1000000; i++) {
        // just run the loop
    }

    end = clock();

    /* calculate elapsed time by finding difference (end - begin) and
     dividing the difference by CLOCKS_PER_SEC to convert to seconds
    */

    timeElapsed += (double)(end - begin) / CLOCKS_PER_SEC;

    printf("Time elpased is %lf seconds\n", timeElapsed);

    return 0;
}
```

Lab3 — -bash — 150×24

```
[Ritus-MacBook-Air:Lab3 ritu$ gcc -Wall sampleProgramTime.c
[Ritus-MacBook-Air:Lab3 ritu$ ./a.out
 Time elpased is 0.003987 seconds
[Ritus-MacBook-Air:Lab3 ritu$ ./a.out
 Time elpased is 0.004325 seconds
[Ritus-MacBook-Air:Lab3 ritu$ ./a.out
 Time elpased is 0.004892 seconds
[Ritus-MacBook-Air:Lab3 ritu$ ./a.out
 Time elpased is 0.003985 seconds
 Ritus-MacBook-Air:Lab3 ritu$
```