McMaster University

COMPENG 2SH4
Principles of Programming
LAB 2: Functions and Arrays
Instructor: Mohamed Hassan

This lab is worth 7% of the course mark.

The number in square brackets at the beginning of each question shows the number of points the question is worth. The total number of points is 70.

General Requirements on Your Programs

A. You will be using the exact same process from Lab0 and Lab1 to accept the invitation→clone the git repo→create the eclipse project→develop your lab code→push to the repo.
B. All lab questions have to be implemented in the provided QuestionXX.c template where XX is the question number.
C. You have to follow the guidelines in the provided comments such that your code passes the tests.
D. Your programs should be written in a good programming style, including instructive comments and well-formatted, well-indented code. Use self-explanatory names for variables as much as possible. (~5% of the mark)
E. You have to make sure you pass all the tests. Please note that passing the tests does not grant you automatically the full mark, we run other "hidden" test cases that are not shared with you to further assess your code. You are required to make sure your work is correctly implemented to the best of your knowledge. One task that can help you with that is to add further tests to stress the corner cases of each question.
F. For each question, you are required to add **at least** one additional test to the testCases.c file.

Lab Github Classroom Invitation Link

https://classroom.github.com/a/mrP8rQOQ

Lab Deadline

The deadline for lab1 is Oct 21. Please note that this is a programmed deadline in the environment, so make sure you submit in time since you will not be able to submit after that dictated deadline.

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Lab Questions

Assume the character code used is ASCII.
You are allowed to use from the C standard library only functions for input and output and math library functions. The use of global variables is not permitted.

1. [10] Consider representing vectors with ***n*** floating point components using arrays. Develop a library for vector operations, that includes the following functions (Use ***Question1.c*** code starter for this question).
   - A function add_vectors() to add two vectors of the same size, with prototype:
     - `void add_vectors(double vector1[],double vector2[],double vector3[],int size)`

     vector3 should store the sum of vector1 and vector2.
     You may assume that all three arrays have the size equal to `size`, which equals the vector dimension. (In other words, assume that the calling function ensures that the arrays passed in satisfy this condition.)
   - A function `scalar_prod()` that returns the scalar product of two vectors of the same dimension. You may assume that the passed in arrays have the same size.
   - A function `norm2()`, which returns the L2 norm of a vector. The L2 norm is defined as the square root of the scalar product of the vector with itself. Function norm2() should call function scalar_prod().

   Write a program to test this library. You **are allowed** to use math library functions.
   Attention: When you pass an array (which is not a string) to a function, you also need to pass to the function the size of the array.
   Note: Consider vectors x=(x(0), x(1), …, x(n-1)) and y=(y(0), y(1), …, y(n-1)).
   The **sum** of x and y is the vector z=(z(0),z(1), …, z(n-1)), where z(i)=x(i)+y(i) for every 0<=i<n.
   The **scalar produ**ct of x and y is the value x(0)y(0)+x(1)y(1)+…+x(n-1)y(n-1).
   Example: Assume n=3 and vectors x=(2,4,6) and y=(0,1,2). Then the sum of vectors x and y is the vector sum=(2,5,8). The scalar product of vectors x and y is the number 0+4+12=16.

2. [10] A diagonally dominant matrix is a matrix A such that for each row, the absolute value of the diagonal element on that row is strictly larger than the sum of the absolute values of all other elements in the row. That is, for each row *i*=0,1,…, n-1, the following holds:

$$|a_{ii}| > \sum_{j=0,\, j\neq i}^{n-1} |a_{ij}|$$

   Complete the function is_diag_dom() in ***Question2.c*** file that determines if an N-by-N matrix mat is diagonally dominant (it returns 1 if the matrix is diagonally dominant and 0 otherwise). The function prototype has to be
   - `int is_diag_dom(int mat[][N2])`

   You may use the function fabs()with prototype
   - double fabs(double x),

   from the C standard math library, which returns the absolute value of x. Write a program to test this

function. Note that `N2` represents a constant. To set a value to `N2` use the define directive. We define `#define N2 3` in the Questions.h header file. This replaces N2 by 3 all over the file, except for occurrences of N2 inside a string or a variable name. Write a program to test the function.

3. [10] Complete the function in ***Question3.c*** file which construct an array of all elements of a square matrix in a diagonal scan order, starting at the top left corner. For instance, for the following matrix

1	12	13	49
5	16	17	81
9	10	11	20
2	45	19	14

the output has to be: 1 5 12 9 16 13 2 10 17 49 45 11 81 19 20 14

The function prototype is:

- `void diag_scan(int mat [][N3], int arr [N3*N3])`

`mat` is the input square matrix, `arr` is the constructed array by the function and `N3` is defined in the Questions.h header file.

Write a program to test the function.

4. [10] Write a C function with prototype

- `void letter_freq(const char word[], int freq[]);`

This function computes the number of appearances of each letter in the string word and stores them in array freq of size 26. The letters are the 26 letters of the Latin alphabet whose ASCII values are in the range 97-122 for the lower case letters, and in the range 65–90 for the uppercase letters. ***You must account for uppercase and lowercase letter variants, which should be counted together.*** The counts have to be stored in array freq in alphabetical order of letters, which corresponds to the increasing order of their ASCII values. Specifically, freq[0] should store the count of 'A' and 'a', freq[1] should store the count of 'B' and 'b', and so on.

Write a program to test the function.

Hint: If variable x of type char represents a lower case letter, then the corresponding index in the array equals the integer value of x-'a'. If x is an upper case letter, then the index in the array equals x-'A'.

5. [10] Write a function with prototype

- `void string_copy(const char source[], char destination[], int n){`

This function copies string source to string destination. Parameter n represents the size of array destination. If the latter array is not sufficiently large to hold the whole source string then only the prefix of the string which has room in the latter array should be copied. Note that after copying, the null character should also be included to mark the end of string destination.

Write a program to test your functions.

You are not allowed to use any function declared in string.h.

You may write a function which returns the length of a string and use it if you need it. **Recall that a string is a char array with the null character marking the end. The length of the string is the number of characters in the array appearing before the null character.**

6. [10] A sparse vector is a vector whose most components are zero. To store a sparse vector efficiently it is enough to store only its non-zero components and their index (position in the vector). The components of a vector are indexed starting from 0, like in C arrays. Precisely, to store a sparse vector with **n** components, only **k** of which are non-zero, we can use two arrays: **val** and **pos**, each of size **k**. For example, if the sparse vector **x** with 8 components is the following

0 0 23 0 -7 0 0 48
then **k**=3 and
val contains 23 -7 48
pos contains 2 4 7

Notice that the elements of array **pos** are in increasing order. We will assume that each vector contains at least one non-zero element.

Write a function efficient() with prototype

- `void efficient(const int source[], int val[], int pos[], int size)`

which computes the efficient representation of vector source, by filling the arrays val and pos. Parameter size represents the number of components of vector source (i.e., the size of the array). Assume that the size of arrays pos and val equals the number of non-zero values of vector source.

Additionally, write a function reconstruct() with prototype

- `void reconstruct(int source[], int m, const int val[], const int pos[], int n)`

which reconstructs vector source from the efficient representation stored in arrays val and pos. Parameter n represents the size of arrays val and pos. Parameter m represents the size of array source, which equals the dimension of the vector.

Write a program to test the two functions.

7. [10] Consider the efficient representation of sparse vectors as in question 6. Write a function with prototype

- `void addEff(int val1[], int val2[], int val3[], int pos1[], int pos2[], int pos3[], int k1, int k2)`

where val1, pos1 and val2, pos2 represent two sparse vectors of integers, stored efficiently. k1 is the number of non-zero elements of vector 1 and k2 is the number of non-zero elements of vector 2. Function addEff() has to add the two vectors and store the result in efficient representation as well, using val3, pos3. Assume that the size of arrays val3 and pos3 equals the number of non-zero elements in the sum vector, but the function does not know this number. **The function is not allowed to allocate any array**, in other words only a constant number of variables may be allocated during the function execution. **No mark is awarded if this requirement is not satisfied.** **Note:** Pay attention to the case when two non-zero elements sum up to 0. You may assume that the two vectors, as well as their sum, are not equal to 0.