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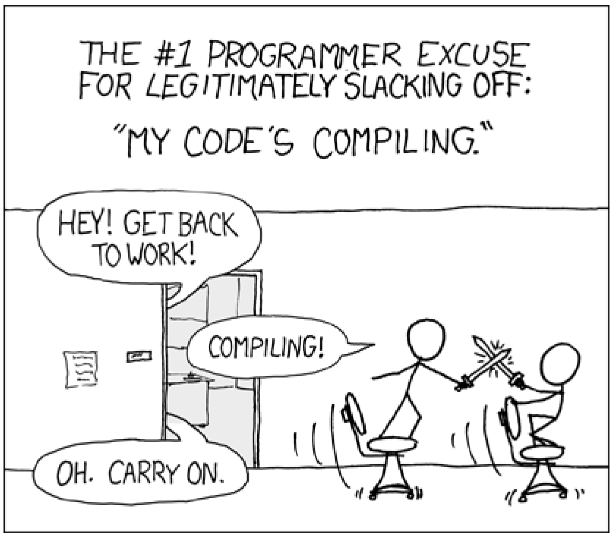
Computer Programming 143

Practical 5

2019

Aim of Practical 5:

- Declare an array and load values (including random values)
- Access array entries using a `for`-loop
- Manipulate an array
- Write a function that uses recursion



Instructions

1. Attendance is **compulsory** for all the practical sessions of your assigned group. See the study guide for more details.

2. The last section (usually the last 30 minutes) of the practical will be used for a test.

3. If more than two tests have been missed for what ever reason, you will receive an **incomplete** for the subject. See the study guide for more details.

4. You must do all assignments **on your own**. Students are encouraged to help each other **understand** the problems and solutions, but each should write his/her own code. By simply copying someone else's code or solutions, you will not build an understanding of the work.

5. You are responsible for your own progress. Ensure that you understand the practical work. Check your work against the memorandum that will be posted on Wednesday afternoons on learn.sun.ac.za.

6. Use H:\CP143 as your Code::Blocks workspace folder for all projects. But it is highly suggested that you also use a **flash drive to backup** all your work.

7. Create a new project **for each assignment**. See *Creating a Code::Blocks Project* in Practical 0 for instructions on how to do this.

8. Include a comment block at the top of each source file according to the format given. It must include the correct filename and date, your name and student number, the copying declaration, and the title of the source file.

9. **Indent your code correctly.** Making your code readable is not beautification, it is a time and life saving habit. Adhere to the standards (refer to the documents on SUNLearn).

10. Comment your code sufficiently well. It is required for you and others to understand what you have done.

Question A

Goal: *Perform operations on a character array.*

Getting started

1. Create a project named `Assignment5A`. Make sure that this is the active project in the workspace before compiling the program.

2. Include the **standard comment block** above your main function. Also, comment your whole program appropriately.

3. Read the complete question before you start programming.

4. Either draw a program flowchart or write the pseudocode **before** you start programming. A demi/instructor may ask to see this when they come to assist you.

Program description

1. In the `main()` function declare one array of type **`char`** with 10 elements. You will be doing the following operations on this array: assign values to it, display it, do an operation on it and once again display it, this time in reverse order.

2. Assign values to the array:

   - Populate the array by reading in a single character at a time from the user, i.e. your program should ask the following:
     ```
     Enter a lower-case character for element 0: a
     Enter a lower-case character for element 1: b
     Enter a lower-case character for element 2: c
     Enter a lower-case character for element 3: z
     ...
     Enter a lower-case character for element 9: i
     ```
     Hint: When using `scanf()` with characters, add a leading space to the first function argument so it does not cause problems when you press enter after entering a single character, e.g.:
     ```
     scanf(" %c", &array[i]);
     ```

   - We only want to accept lower-case characters, i.e. from `'a'` to `'z'`. Your program needs to keep asking the user until a lower-case letter is entered. **`char`** is internally represented as a limited range integer. By checking whether this value is in the range [97, 122] we can determine if the number is a lower-case number.

   - Why is the chosen range [97,122]? These are the numbers that represent 'a' to 'z' in ASCII code, i.e. lower-case letters. The ASCII standard assigns a number to most alpha-numerical characters. For example the character for '1' is represented by the number 49 in this code, 'a' is 97, 'b' is 98 and so forth, while 'A' is 59, 'B' is 60 and so forth.

- Have a look at Lecture 6 slide 15 to see where we discussed some of these things in class.

3. Display the array:
   Step through the array and display the index of the array element as well as the value of the array element. Your output should look something like this:
   ```
   Array values:
   Element 0: a
   Element 1: b
   Element 2: c
   Element 3: z
   ...
   Element 9: i
   ```
4. Do a mathematical operation on the array:
   Step through the array and subtract 32 from each character, and store the new value in the array. Note that doing operations like these must be done element by element—you **can't** say `arrName = arrName - 32` (although in some other computer languages you can).

5. Display the array a second time:
   Once again display the index and values of the array, but this time in **reverse** order according to its index, i.e. display the last element first and the first element last. What was the effect of subtracting 32 from each of the elements, and why did this happen?

Something to think about: The American Standard Code for Information Interchange, better known as the ASCII code, is used worldwide to represent characters in numerical format. Computers can only "understand" numbers. Everything that happens on your computer, from the amazing graphics of your latest game, or the assignments you write for your degree to the music you listen to, are only numbers to the computer.

Backup instructions

1. Ensure that your code is indented correctly and that the { } braces are on the correct lines. Use the prescribed textbook as guideline.

2. Ensure that you copy the **Assignment5A** project folder to a flash drive as a backup.

Question B

Goal: *Perform operations on a numerical array with functions.*

Getting started

1. Create a project named `Assignment5B`. Make sure that this is the active project in the workspace before compiling the program.
2. Include the **standard comment block** above your main function. Also, comment your whole program appropriately.
3. Read the complete question before you start programming.
4. Either draw a program flowchart or write the pseudocode **before** you start programming. A demi/instructor may ask to see this when they come to assist you.

Program description

1. In the `main()` function declare an array of type **`int`** with 11 elements. You will be doing the following operations on this array: assign values to it, display it, do a sort on it, display it again, and calculate the average—all using functions.
2. You will write four functions; all of them will be called with the array and the size of the array as arguments. The four function prototypes could be defined as follows:

   ```
   void assignRandArray(int array[], int sizeOfArray);
   void displayArray(int array[], int sizeOfArray);
   void sortArray(int array[], int sizeOfArray);
   float averageOfArray(int array[], int sizeOfArray);
   ```

   The four functions are described in the following points. You will call all of these functions from `main()`.
3. Assign values to the array:
   - Write a function that receives a integer array by reference and its size by value. This function should then populate the array with random integers in the inclusive range of 4 to 115, mathematically shown as $[4, 115]$. This can be done using the library function `rand()`.
   - Have a look at the slides for Lecture 11 which explains this function fully.
   - Before using the `rand()` function you should seed it with a value. The most common is with time. We use the function `srand(time(NULL))` to seed the random generator. The function `time` returns a value that the function `srand` uses to seed the random number generator. To use `time` include the library `<time.h>`. To see the effect this has, finish the next point of displaying the array values, then do the following: Comment the call to `srand` out. Run your program a number of times and note the values that are generated and stored in the array. Now put the call to `srand` back. Run it again a couple of times and once again note the values that are generated each time. Makes a difference, doesn't it?

4. Display the array:
   Write a function that receives an integer array by reference and its size by value. The purpose of this function would simply be to step through the array and display the index of the array element, as well as the value of the array element. Example output could look look like the following:

```
Element 0: 13
Element 1: 27
Element 2: 90
Element 3: 5
Element 4: 75
Element 5: 4
Element 6: 26
Element 7: 15
Element 8: 113
Element 9: 9
Element 10: 25
```

5. Sort the array:
   Write a function that receives an integer array by reference and its size by value. The purpose of this function would be to sort the array using bubble sort. You can refer to your textbook/lecture slides on how to code bubble sort or you can follow either one of the following pseudocode examples. (The algorithm is exactly the same for the two pseudocode examples. The only reason why it is given twice is to show you that different wording is acceptable in pseudocode.)

   Bubble sort - pseudocode example 1:

```
/*
 * begin function bubbleSort(reference to array arr, size)
 *    for pass from 1 to (size - 1) in increments of 1
 *       for i from 0 to (size - 2) in increments of 1
 *          if (element i of arr) > (element (i+1) of arr)
 *             //swap the the values in these two elements
 *             hold = element i of arr
 *             element i of arr = element (i+1) of arr
 *             element (i+1) of arr = hold
 * end function
 */
```

   Bubble sort - pseudocode example 2:

```
/*
 * begin bubbleSort(reference to array arr,size)
 *    for pass in range [1, size) in increments of 1
 *       for i in range [0, (size - 1)) in increments of 1
 *          if arr[i] > arr[i+1]
 *             //swap the the values in these two elements
 *             hold = arr[i]
 *             arr[i] = arr[i+1]
 *              arr[i+1] = hold
 * end
 */
```

6. Display the array a second time:
   To display the array again, **do not** write another function—just call the function that you have already written in point 4. Example output could look look like the following:
   ```
   Element 0: 4
   Element 1: 5
   Element 2: 9
   Element 3: 13
   Element 4: 15
   Element 5: 25
   Element 6: 26
   Element 7: 27
   Element 8: 75
   Element 9: 90
   Element 10: 113
   ```
7. Write a function that receives an integer array by reference and its size by value, and returns a `float`. The returned value should be average of the elements in the array. Call this function from `main()` (as you did the other functions), and then display the average.

One way to think of the above program: The program you wrote above sorts and calculates the average of an array of 11 integers. One setting where this would be useful is in recording the batting scores of a cricket team (which consists of 11 players). Simple functions like the ones you wrote here forms part of many data processing applications; it could be used, for example, in a bigger program that keeps track of cricketers' batting scores, averages, strike rates, etc.

Backup instructions

1. Ensure that your code is indented correctly and that the { } braces are on the correct lines. Use the prescribed textbook as guideline.
2. Ensure that you copy the **Assignment5B** project folder to a flash drive as a backup.

Question C

Goal: *Write two recursive functions.*

Getting started

1. Create a project named `Assignment5C`.
2. Include the **standard comment block** above your main function. Also, comment your whole program appropriately.
3. Read the complete question before you start programming.
4. Either draw a program flowchart or write the pseudocode **before** you start programming. A demi/instructor may ask to see this when they come to assist you.

Program Description

1. For this question you will write two recursive functions and the `main()` that will call them. The first recursive function will simply print a counter to the screen. The second one will find the greatest common divisor between two given integers.

   (a) The "print a counter" function:
   Write a recursive function that takes no arguments and returns nothing. It should print a counter value to the screen. It must be the recursive equivalent of the following `for` loop:

   ```
   int x;
   for (x = 0; x < 10; x++ ) {
       printf("\n%d", x);
   }
   ```

   Hint: make use of a `static` variable.
   The function prints the counter, increments the counter and then calls itself again if the counter has not reached the desired value.

   (b) The GCD (greatest common divisor) function:
   Given two integers, find the biggest integer that divides evenly into both – in other words, find the greatest common divisor (GCD). For example: the GCD of 20 and 10 is 10, the GCD of 99 and 100 is 1, and the GCD of 12 and 42 is 6.

   We will calculate the GCD recursively using **Euclid's algorithm**. This algorithm is built on the following property of the GCD:

   $$\operatorname{gcd}(x,y) = \begin{cases} x & \text{if } y = 0 \\ \operatorname{gcd}(y, x \bmod y) & \text{if } y \neq 0 \end{cases}$$

   Notice that this definition of the GCD operator includes the operator itself on the right-hand side – in other words, it is defined **recursively**.

   We will create a recursive function called `gcd(int x, int y)`, which will implement this equation. If the second number is zero, it will simply return the first number; otherwise, it will call itself recursively.

For example, the GCD of 180 and 24 can be calculated as follows:

$$\begin{aligned}\gcd(180,24) &= \gcd(24,180 \bmod 24) = \gcd(24,12)\\ \gcd(24,12) &= \gcd(12,24 \bmod 12) = \gcd(12,0)\\ \gcd(12,0) &= 12\end{aligned}$$

(c) The calling function:
Your `main()` function will be the calling function for the other two. Ensure that you only have the function prototypes above the `main()` function. Call the "print a counter" function first. Call and print the results of the "greatest common divisor" function with the following pairs of values: 10 and 20; 20 and 10; 777 and 99; 345 and 6000.

Face the world: In 1844 it was proven that, if the smallest number has n digits, Euclid's algorithm never takes more than $5n$ recursion steps to calculate the GCD. This means that the time a computer will take to find a GCD is a *logarithmic* function of the size of the numbers.
This was one of the first results in analysing the *computational complexity* of algorithms, which is the focus of a lot of the work done in computer science. You may have different algorithms that can perform the same function, but their running times may depend differently on the amount of input data. The best algorithms are the ones that run in *constant time* – their running time is independent of the amount of data. Then you get, in increasing order of complexity, algorithms that run in *logarithmic time*, *linear time*, *polynomial time* (e.g. quadratic), and *exponential time*. If you have a large amount of data, the difference in running time between a linear algorithm and a logarithmic one can be huge.
There will often be one possible algorithm which is very easy to implement, but is computationally inefficient, while another algorithm will be more efficient but harder to implement. The different sorting algorithms are good examples of this – there are simple but inefficient algorithms such as Bubble Sort, and more efficient ones such as Quick Sort that are harder to implement.

Backup instructions

1. Ensure that your code is indented correctly and that the { } braces are on the correct lines. Use the prescribed textbook as guideline.

2. Ensure that you copy the **Assignment5C** project folder to a flash drive as a backup.