

Tutorial 07 - 21.12./07.01.2021

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Higher-Order Functions, Pointers

Today's Agenda

- Higher-Order Functions
- Pointers
- **Exercise 7.1: Pointers**
- Functions and Pointers
- Arrays and Pointers
- **Exercise 7.2: Arrays and Pointers**
- Structs and Pointers
- **Exercise 7.3: Practice Project - Stacks**

Higher-Order Functions

Higher-order functions are functions which receive a function as a parameter and use that function inside their body.

By using this feature you can create logic with less code and less functions.

Higher-Order Functions - Examples

Classic examples of higher order functions are:

- `map` : Apply a function to every element of an array
- `filter` : Given some array, remove all elements for which a given function returns false (`0`)

See `example_7_1_ho_map_function.c` and `example_7_2_ho_filter_function.c`.

Higher-Order Functions - Notation

```
void map(int (*func)(int), int *array, int length) {  
    for (int i=0; i<length; i++) {  
        array[i] = func(array[i]);  
    }  
}  
  
int times_2(int x) {  
    return 2 * x;  
}  
  
int main() {  
    int my_array[10] = {1,2,3,4,5,6,7,8,9,10};  
    map(times_2, my_array, 10);  
}
```

*You **do not** have to fully remember this notation! Just keep it on your cheatsheet or know where to look it up.*

What are Pointers?

Every time we create a variable, its value has to be stored somewhere in memory.

Each slot in memory has a specific address.

A pointer is simply an address of a slot in memory.

See `example_7_3_pointer_intro.c`

Getting the Address of a Variable

This is also called "Referencing".

Every pointer also has a type which is equal to type of its corresponding variable.

```
int *my_pointer; // points to a memory slot which stores an integer
```

The star marks that `my_pointer` - which you can name however you want - is a pointer.

You can get the actual address of a variable by using `&`:

```
int my_var = 55;  
int *pointer_to_my_var = &my_var;
```

Getting the Value Belonging to a Pointer (Address)

This is also called "Dereferencing".

You can get the corresponding value by using `*`:

```
int my_var_copy = *pointer_to_my_var; // my_var_copy now also stores 55
```

```
printf("\nADDRESS of my_var = %p", pointer_to_my_var); // prints 0x7ff...  
printf("\nVALUE of my_var = %d", my_var); // prints 55  
printf("\nVALUE of my_var = %d", *pointer_to_my_var); // prints 55
```


Exercise 7.1: Pointers

- (a) Given `char c = 'K';`, what kind of type would I need to hold `&c` ?
- (b) Given `float *ff`, what kind of data does `ff` hold?
- (c) Given `char *c`, what exactly is `&c` ?
- (d) What, if anything, is wrong with the following code?

```
int main(void) {  
    char *some_value;  
    char my_value = '!';  
  
    some_value = my_value;  
  
    return 0;  
}
```

Revision: Passing Data to Functions

What will be printed out?

```
void add_10(int value) {  
    value += 10;  
}  
  
int main() {  
    int my_value = 5;  
    add_10(my_value);  
    printf("My value is %d\n", my_value);  
  
    return 0;  
}
```

See `example_7_4_passing_by_value.c`.

What happens inside `add_10` ?

```
void add_10(int value) {  
    // A local copy of "value" gets created  
    value += 10;  
    // The local copy now stores 20  
}
```

To get this local variable "out of" the scope of `add_10` we'd have to include a `return` statement and a "re-assignment" inside `main`.

This way of passing data to functions is also called "passing by value".

Passing Data by Reference

You can also pass the pointer of a variable. Any copy of that pointer still points to the same slot in memory. And we don't modify the pointer itself but the memory space it points to.

```
void add_10(int *value) {  
    *value += 10;  
}  
  
int main() {  
    int my_value = 5;  
    add_10(&my_value);  
    printf("My value is %d\n", my_value); // prints 15  
  
    return 0;  
}
```

See `example_7_5_passing_by_reference.c` on GitHub.

Arrays and Pointers

An array variable is actually a pointer to the first element of the array.

```
int main() {  
    int my_array[10] = {0,1,4,9};  
  
    printf("ADDRESS of the 1st element = %p\n", &(my_array[0]));  
    printf("ADDRESS of the 1st element = %p\n\n", my_array);  
  
    printf("ADDRESS of the 2nd element = %p\n", &(my_array[1]));  
    printf("ADDRESS of the 2nd element = %p\n\n", my_array + 1);  
  
    printf("VALUE of the 3rd element = %d\n", my_array[2]);  
    printf("VALUE of the 3rd element = %d\n", *(my_array + 2));  
  
    return 0;  
}
```

See `example_7_6_array.c` on GitHub.

See `example_7_7_array_index_access.c` on GitHub.

See `example_7_8_array_pointer_access.c` on GitHub.

Exercise 7.2: Arrays and Pointers

```
char string_buffer[1000];  
char *my_char_ptr = string_buffer;
```

- (a) What kind of data would `my_char_ptr` be?
- (b) What about `*my_char_ptr` ?
- (c) What about `*string_buffer` ?
- (d) Let's say you want to store `&(string_buffer[2])` somewhere. What type of variable do you need to store this?

(e) What is wrong with the following code?

```
char old_buffer[1000];  
char *my_char_ptr = &old_buffer;
```

(f) What is wrong with the following code?

```
char old_buffer[1000];  
char new_buffer[1000];  
new_buffer = old_buffer;
```

(g) If you pass an array to a function and you change elements of the array in the function, what do you think happens when you leave the function?

Structs and Pointers

There is a shortcut in accessing element inside a struct, that is present as a pointer.

```
struct Point {  
    float x,  
    float y,  
    float z  
};  
  
struct Point *pointer_to_struct;
```

Access by dereferencing the struct first

```
(*pointer_to_struct).x = 1.2;
```

Clean version (does exactly the same):

```
pointer_to_struct->x = 1.2;
```

Exercise 7.3: Practice Project - Stacks

Some background information about stacks: A stack is similar to a list but a stack only allows certain types of operations on its contents.

There are two main methods you can perform on a stack:

- **push** : Add an element to the stack (in case its storage capacity is not reached)
- **pop** : Remove and return the most recently added element from the stack (in case the stack is not empty)

In german it is officially called "Keller", however "Stapel" is probably a better name.

You can have further read about Stacks on Wikipedia:

[https://en.wikipedia.org/wiki/Stack_\(abstract_data_type\)](https://en.wikipedia.org/wiki/Stack_(abstract_data_type))

Your tasks

Download this folder from GitLab: `tutorial-07/exercises/stack_boilerplate`

This folder includes three files: `stack.c`, `stack.h` and `main.c`. Compile them with:

```
gcc -Wall -Werror -std=c99 stack.c main.c
```

... or inside the CMake file:

```
add_executable(  
    stack_boilerplate  
    exercises/stack_boilerplate/stack.c  
    exercises/stack_boilerplate/main.c  
)
```

Tasks: Implement the functions marked with `\\YOUR CODE HERE` so that the Stack behaves like it is supposed to.

You can modify `main.c` as you like to test all of the functionality.

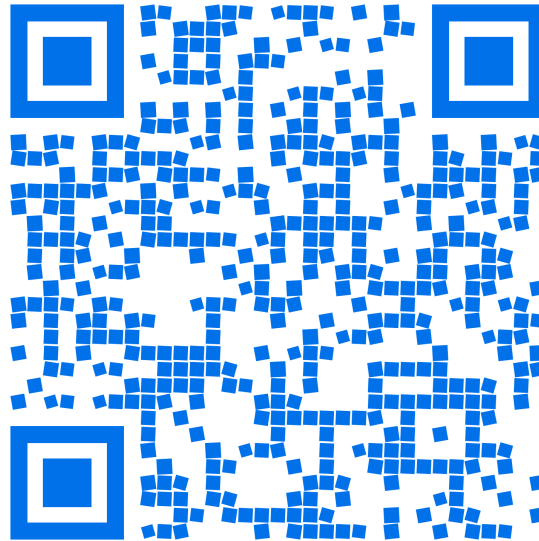
You can also test your implementation with a proper test procedure:

```
gcc -Wall -Werror -std=c99 stack_boilerplate/stack.c stack_solution/main_correction.c
```

See You Next Week!

All code examples and exercise solutions on GitLab (solutions right after my tutorial):

<https://gitlab.lrz.de/dostuffthatmatters/IN8011-WS20>



When you copy a snippet from
StackOverflow and it doesn't work

