EEE243 – Applied Computer Programming

Modules and Information Hiding and Function Pointers

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RMC CMR

Outline

1. Modular Decomposition
2. Information Hiding
3. Encapsulation
4. Interfaces
5. Modules in C
6. The Right-Left Rule
7. Pointers to functions

Modular decomposition

- So far we have seen that we can decompose a large monolithic function (such as `main()`) into many smaller and *cohesive* functions

- Up to now, all of the functions that we have defined have been defined into one program file
  - *a single compilation unit*

- We have also learned about *function prototypes*, and how to declare them within our program file.

Modular decomposition

- Well designed software, like any other product of engineering, should be designed with a *philosophy of planning and careful implementation*
- Similar to an office building, a software program should have a well-designed structure
  - *an architecture*

Modular decomposition

- It is not sufficient to decompose a large program into functions
- The architecture of a large program should be expressed into separate compilation units
- These separate compilation units in C are called *modules*
- You already have used several library modules such as `stdio`, `string`,…

Information Hiding

- The concept of information hiding originates from a seminal paper from David Parnas (1972)

- Information hiding:

  "*Each module has a secret which it hides from other modules*"

Encapsulation

- The concept of information hiding is key to the concepts of *decomposition* and *abstraction*

- *Hide* the information that *can* or *may change* and *expose* a stable *interface* that will ***NOT*** *change*
  - This is known as encapsulation

- The information is **ONLY** accessed through the interface, never directly – it is hidden

Encapsulation

Why is information hiding important?

- By *encapsulating* the information that can change in the module implementation and providing the *service* through a *stable interface*, we free the user of the module from the need to know about the implementation
- The implementation can change to improve the performance
  - Due to hardware/platform changes…
- The *coupling* between modules is therefore reduced.
  - The program is *more maintainable*

What do we hide?

There are three types of information hiding modules:

- *Behaviour-Hiding*: Hides items such as screen formats, print formats, user menus, communication of data, change in state etc…
- *Design Decision-Hiding*: Hides the kind of data structures and algorithms you use
- *Machine-Hiding*: Hides platform specific interfacing
  - Ex: `3pi.h` – hides the `3Pi`-specific functions and some types

Interface

Interface

```
float multiplication (float x, float y);
```

Interface

```
float multiplication (float x, float y);
```


```
float multiplication(float x, float y) {
    float res = 0;
    for (int i = 0; i < y; i++) {
        res += x;
    }
    return res;
}
```

Interface

```
float multiplication (float x, float y);
```


```
float multiplication (float x, float y){
    return x*y;
}
```

The C Module

C provides two different kinds of files that allow us to define modules

- The `.h` file – or module header: Contains the *declaration* of functions and attributes that we want other compilation units to have access to. AKA the **module interface**

- The `.c` file – or module body: Contains the *definition* of the functions that are declared in the module header as well as other internal or helper functions. AKA the **module implementation**

The C Module

- When you #include a module header in your program, only the functions and attributes that are declared in the header are available to you

- When designing a module it is NEVER a good idea to give direct access to the module's variables
  - Certainly, it is not a good approach to, say, a question on an exam.

The C Module - Prototypes

- A module must have two files with the same name but with the `.c` and `.h` extensions
  - `app.c`, `app.h`

- You must declare a function prototype in the header file for each of the functions that you want to make accessible to other modules

Example – great_small.c

```
#include <stddef.h>
#include <stdlib.h>
#include <stdio.h>
#include "compare.h"

int main(void) {
  int first = 5;
  int second = 10;
  int *p_greater  = NULL;
  int *p_smaller = NULL;
  p_greater = greater_of(&first, &second);
  p_smaller = smaller_of(&first, &second);
  printf("Greater: %d   Smaller: %d\n", *p_greater,
       *p_smaller);
  return EXIT_SUCCESS;
}
```

Example – compare.h

```c
#ifndef COMPARE_H_
#define COMPARE_H_

/*
 * returns: a pointer to the greater of of *px and *py
 */
int* greater_of(int* px, int* py);

/*
 * returns: a pointer to the smaller of of *px and *py
 */
int* smaller_of(int* px, int* py);

#endif /* COMPARE_H_ */
```

Example – compare.c

```
/*
 * returns: a pointer to the greater of of *px and *py
 */
int* greater_of(int* px, int* py){
   return (*px > *py ? px : py);  //another compact way
for if statement
}

/*
 * returns: a pointer to the smaller of of *px and *py
 */
int* smaller_of(int* px, int* py){
    return (*px < *py ? px : py);
}
```

Building with components

- As modules are developed worldwide, libraries and reusable *components* emerge
- These components are either *full executable* solutions *or parts* to be assembled into larger systems
- Information hiding and abstraction make it possible to build solutions from known components without knowing how they are built

The Right-Left Rule

List of symbols and their translation:

Symbol	Read as
*	“pointer to”
[]	“array of”
()	“function returning”

The Right-Left Rule

1. Find the identifier, it is your starting point. Say “<identifier> is”
2. Look to the right of the identifier. If you find a [], you know the declaration is for an array. Then, you say “<identifier> is an array.” Continue to the right until you run out of symbols or you encounter a closing parentheses.

The Right-Left Rule

3. Look to the left of the identifier. If it is not one of the symbols in the table (e.g. *int*), you say its name (e.g. "int"). Otherwise, use the conversion table. Continue left until you run out of symbols or you reach an opening parentheses.

   - *If you encounter function parameters, say "function taking <parameters> and returning."*
   - *If the array size is part of the declaration, say "array (size<x>) of."*

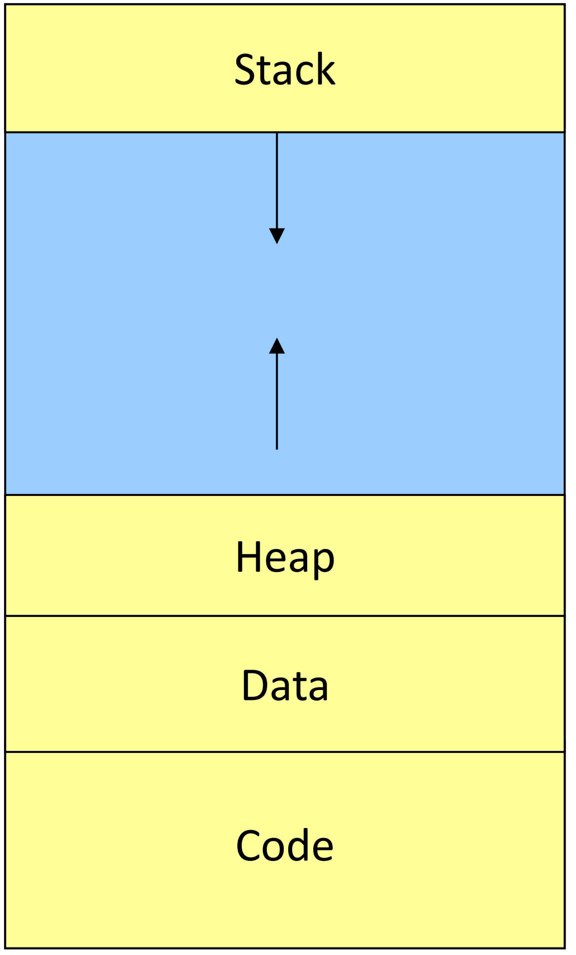
The Right-Left Rule

Examples:

```
int *p[]          //p is an array of pointers to int

char hello()  //hello is a function returning a char

double z[10]  //z is an array (size 10) of double

void do_nothing(int x)

int f[40][1000]  //f is an array size 40 of arrays size 1000 of
                 int
```

Pointers to functions

Functions occupy space in memory just like any other code entities, such as variables, arrays and structures…

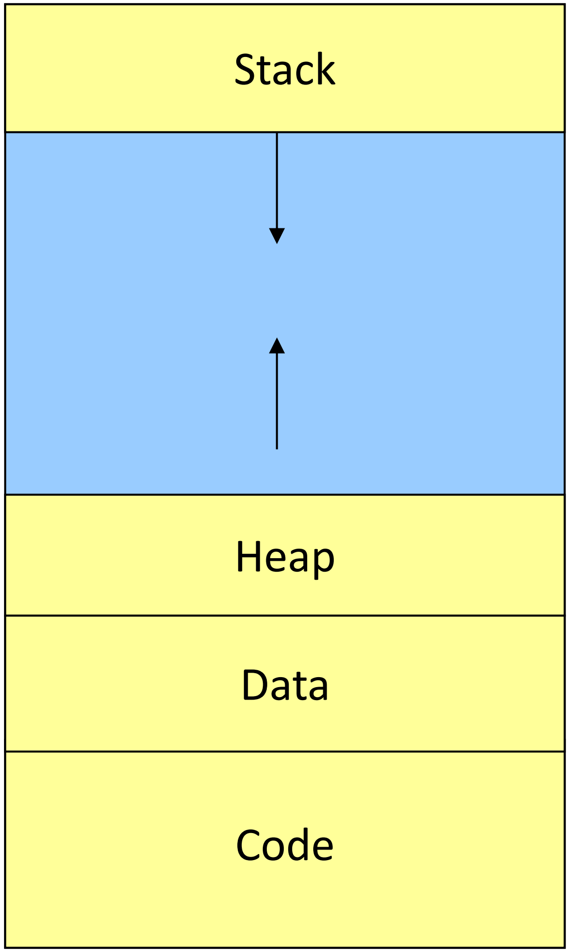


Pointers to functions

The name of a function is a pointer constant similar to the name of an array

It is therefore possible to have pointer variables that can point to functions

An array name refers to an address that does not change during the execution of a program.



Pointers to functions

- The syntax for the declaration of a pointer to a function is different than other pointers
- Remember that a pointer to a variable is declared with the *type* of the pointer, the * and then the *name* of the pointer variable:

```
int *p_int; //a pointer to an int

char *p_char //a pointer to a char
```

Pointers to functions

The declaration syntax for a pointer to a function is similar to a prototype declaration

- It starts with the *type* of the function (what the function returns),
- the *name of the pointer variable in parentheses*
- the *parameter types* in parentheses :

```
int (* fp_ints) (int, int);
void (* fp_Convert) (char);
char *(* fp_String) (char*, char*);
```

Pointers to functions

- Main uses of pointers to functions
  1. One of use for a function pointer is to pass the name of a function (its address) to a task manager;
  2. Execute a function without knowing the name before runtime

The flexibility afforded by pointers to functions is key to our ability to build ***dynamic*** systems

Example

```
#include <stdio.h>

int addition(int a, int b);

int main(void) {
   int (*fonctions[4])(int,
          int) = {addition, difference, multiplication,
          division };

   …
   result = (*fonctions[choice - 1])(param_1, param_2);

   printf("The result is %d\n", result);

   return EXIT_SUCCESS;
}
```

Questions?