




UESTC 1005 - Introductory Programming

Lecture 6 - Modular Programming

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Lecture Outline

- Nested Loops 
- Modular Programming 
- Functions in C
- Scope - Program Organisation 



Nested Loops



Nested Loops

Example - Creating a Pyramid

- Last week, we looked at `for` loops. We can have loops *within* loops
- Let's make a pyramid of `*` using nested `for` loops

	1	2	3	4	5	6	7
1	a_{11}			*		...	a_{17}
2			*	*	*		
3	a_{31}	*	*	*	*	*	
4	*	*	*	*	*	*	*

Example - Creating a Pyramid

- Thinking of the screen as a 2D grid or matrix
- Need to build a logic to display and `*` on screen
- starts off with `n-1` and decreases by ``1``` after each iteration
- `*` starts from `1`
- `nth` row has `2n - 1` stars

	1	2	3	4	5	6	7
1	a_{11}			*		...	a_{17}
2			*	*	*		
3	a_{31}	*	*	*	*	*	
4	*	*	*	*	*	*	*

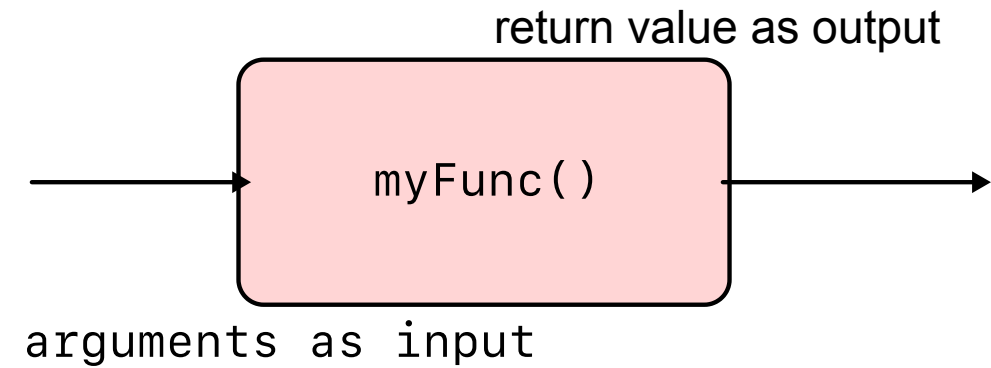
Example - Creating a Pyramid

```
void printDiamond(int n)
{
    int T = n;
    char x = ' ';
    char y = '*';
    for (int i = 1; i <= n; i++)
    {
        for (int j = 1; j <= T; j++) {
            printf("%c", x);
        }
        for (int j = 1; j <= 2 * i - 1; j++){
            printf("%c", y);
        }
        printf("\n");
        T--; //
    }
}
```

Functions

- Functions are essentially small blocks of code that perform a specific task
Using functions makes the code *tidy*
- *Divide and conquer* strategy of problem-solving
- We have seen functions like `scanf()` and `printf()` before

```
return_type function_name (arguments);
```



Basic Functions

```
double sum (double in1, double in2){
    return in1 + in2;
}

double average (double in1, double in2){
    return (in1 + in2)/2;
}

int main(){
    double a = 3.13;
    double b = 5.53;
    printf("The sum of %lf and %lf is %lf", a, b, sum(a,b));
    printf("The average of %lf and %lf is %lf", a, b, average(a,b));
    return 0;
}
```

Here `sum` and `average` are the names of the functions that *accept* as input two `double` type variables. Both functions return `double` type outputs once they are called.

Defining a function

```
return_type function_name (arguments)
{
    //declarations
    //statements
}
```

- Whenever we pass a variable as an argument to the function, we always **copy** its value
- A function can only *return* a single value
- We can also use `void` to indicate, a function doesn't return anything

Calling a Function

- Whenever a function is called, we need to pass on the list of arguments

```
average(a,b);  
sum(a,b);
```

WRONG ✗

```
average;  
sum();
```

Function Declaration

- Typically, we define the function *before* it is used, say in the `main()` function.

```
int main(){
    double a = 3.13;    double b = 5.53;
    printf("The average of %lf and %lf is %lf", a, b, average(a,b));
    return 0;
}
double average (double in1, double in2){
    return (in1 + in2)/2;
}
```

- The compiler does not know what `average(a,b)` is about
- In this case, we can use *function prototype* or *declaration* before the `main()` function

```
double average (double, double);
```

can be placed above the main function.

Some Built-in Functions

- Just like we have used `scanf()` and `printf()` functions, there are various other functions that we can use without defining them
- `math.h` library contains definitions of common mathematical functions

```
#include<math.h>
#include<stdio.h>

int main(){
    double pi = 3.14159;
    double trig_sin = sin (pi/4);
    printf("sine of %lf is %lf", (pi/4), trig_sin);
    return 0;
}
```

Passing Arguments *by value*

- We have to be careful ⚠ when passing the values as an argument.
- The list should exactly match and be in order as in the definition of the function
- When *passing by value* the original variables are not modified.

The diagram illustrates the process of passing arguments by value. It shows a function call `average(a, b);` at the top and its definition `double average(double a, double b);` at the bottom. The parameters `a` and `b` in the call are connected by lines to the parameters `a` and `b` in the definition, demonstrating that the values are passed to the function's local parameters.

```
average(a, b);  
  
double average(double a, double b);
```

Passing Arguments *by reference*

- In short we *modify* the value of the original variable passed to the function
- More about this when we study pointers.
- For now, recall:

```
scanf( "%d" , &v ) ;
```

The `&` is the address operator used when we are going to pass the arguments by reference.

Questions ?

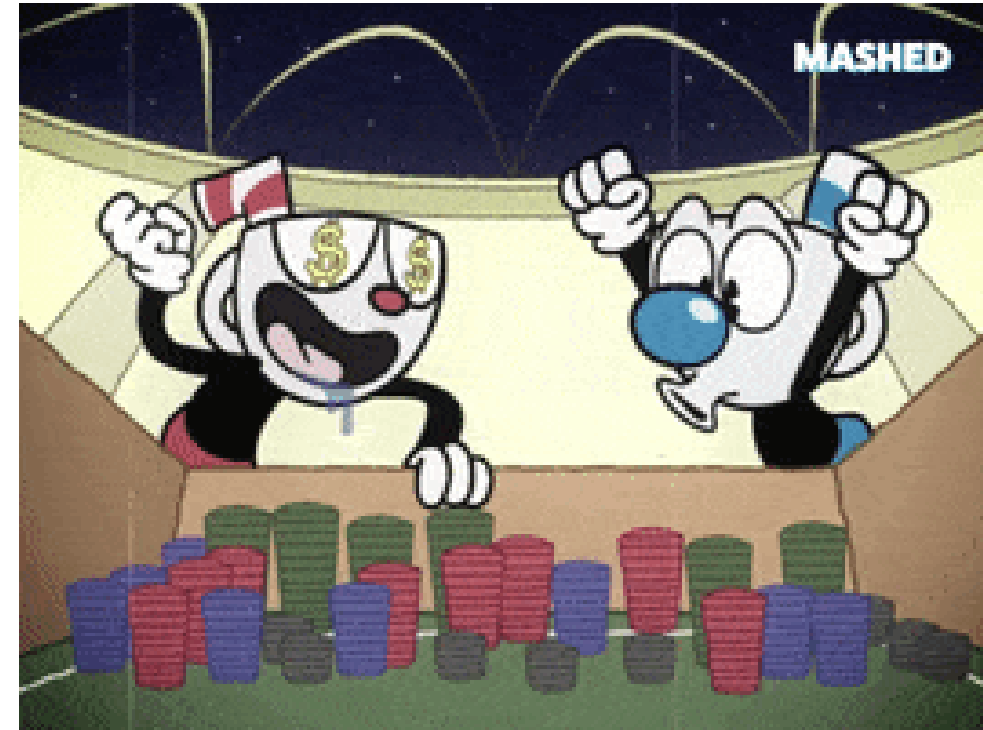
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Example - Make our Own Game 🗝️

- Let's use random number generation which is part of your lab programming exercises, where you are asked to create a `getRand()` function.
- C has `rand()` function that generates a random integer number between 0 and `RAND_MAX()` (compiler dependent).
- Definition of `rand()` is stored in `stdlib.h` library.
- Intuitively, the results should be *completely* random whenever they run the code. However, by design, this is **not** the case.



Example - Random Number Generation

```
#include <stdio.h>
#include <stdlib.h>



int main (){
    // loop 20 times
    for (int i = 1; i <= 20; ++i) {
        // pick random number from 1 to 6
        printf("%10d", 1 + (rand() % 6)); // random # from 1-6

        // For formatting, move to new line after five results
        if (i % 5 == 0) {
            printf("\n");
        }
    }
}
```

- We get the same output, *every time* we run the code
- This is called **pseudorandom number generation**

Example - True Random Number Generation

The `srand()` function

- Generate more randomisation through a seed value
- Different seed value leads to different random numbers generated
-  Same seed values still lead to the same set of random numbers
-  introduce the system clock within `srand()`

```
srand(time(NULL)); // randomise using current time
```

- `time()` function is defined in the library `time.h`
- `NULL` refers to a *symbolic constant*. More on it in pointers.

Example - The Guessing Game 1 2 3 4

- *Randomly* pick an integer between 1 and 32.
- Write a function to guess the number. The function must:
 - Accept one integer (correct answer) as an argument,
 - Read an `int` from the keyboard,
 - *Compare* the input with the correct answer,
 - Based on the comparison, displays an appropriate output such as `correct`, `too high`, or ``too low``.
 - Returns a `1` if the user's guess was correct, and `0` if the user's guess was wrong.
- Give the user five chances to guess the correct answer
- Prints a message on the screen. For example, `You Win` or `You Lose`

The Guessing Game

Random Number Generation

```
// Generate a random number between 1 and 32
int getRand()
{
    return 1 + (rand() % 32);
}
```

The above function returns a value between 1 and 32.

The Guessing Game 12 34

The `GuessNumber()` Function

```
int GuessNumber(int input){
    int guess;
    printf("Guess a number between 1 and 32:\n");
    scanf("%d", &guess);
    if (guess == input){
        printf("Correct!\n");
        printf("You Win!\n");
        return 1;
    }
    else if (guess < input){
        printf("Too Low\n");
    }
    else{
        printf("Too High\n");
    }
    return 0;
}
```

The Guessing Game

The Preamble

```
#include <stdio.h>
#include <stdlib.h> // includes the srand() and rand() functions
#include <time.h> // includes the time() function

#define tries 5 // A directive to define a constant
```


The Guessing Game 12 34

The `main()` Function

```
int main(){
    srand(time(NULL)); // initialise the randomisation process
    int correct_answer = 22;
    int guess;
    for (int i = 1; i <= tries; i++){
        guess = GuessNumber(correct_answer);
        if (guess == 1){
            return 0;
        }
        else{
            continue;
        }
    }
    printf("You Lose!");
    return 0;
}
```

Program Organisation

The Scope

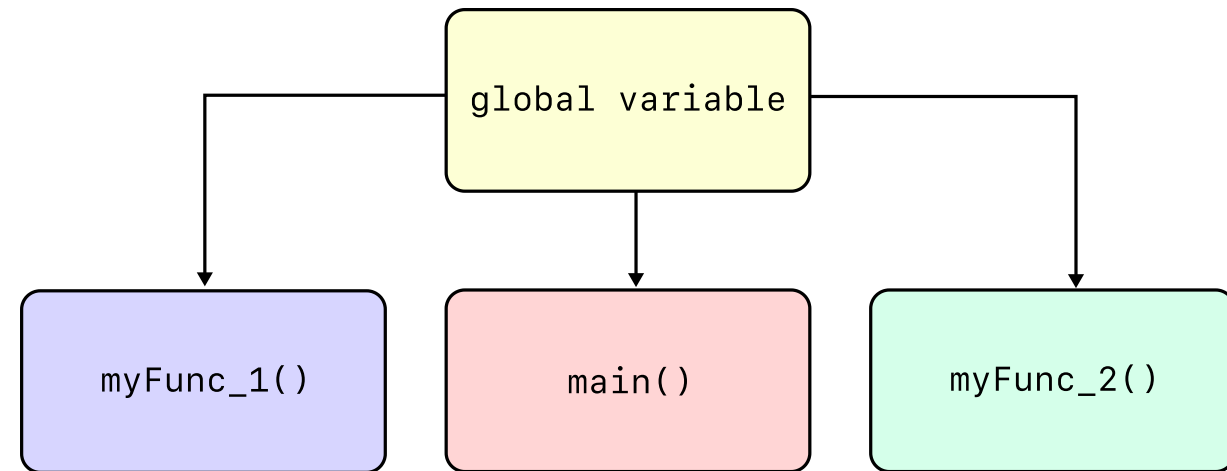
-  Caution is needed when passing variables from one function to another in a program
- C has local, and external (global) variables
- *Local variables* are only **visible** inside a given function
- With each function call, by default, the value of a local variable is **lost**
- We can `static` local variables that preserve the value in different function calls. Variable is allocated to the same location in the memory.

Program Organisation

Global Variables

- We have seen that passing arguments is one way to *exchange* information
- Another way is to use a global (external) variable
- Their scope is throughout the file i.e., all functions can see the variable value]
- Their storage is static

```
int size = 0; // declare outside the functions
```



Quiz ?

What is the output of the following program?

```
#include <stdio.h>
int i;
void print_one_row(void){
    for (i = 1; i <= 4; i++){
        printf("*");
    }
}
int main(){
    for (i = 1; i <= 4; i++){
        print_one_row();
        printf(" ");
    }
    return 0;
}
```



Recursion

The process of a function *calling itself*



Example - Recursion 🧑

Some mathematical functions are ideal cases of recursion.

$$n! = n \times (n - 1)!$$

```
#include <stdio.h>
int factorial(int n){
    while (n >= 1){
        return n * factorial(n - 1);
    }
    return 1;
}

int main(){
    int n = 3;
    int factor = factorial(n);
    printf("Factorial of %d is %d\n", n, factor);
    return 0;
}
```

Example - Recursion

Another one, the power function

$$x^n = n \times x^{n-1}$$

```
#include <stdio.h>
int power(int x, int n){
    if (n == 0){
        return 1;
    }
    else{
        return x * power(x, n - 1);
    }
}

int main(){
    int n = 3;
    int x = 5;
    int pow = power(x, n);
    printf("Power of %d wrt %d is %d\n", x, n, pow);
    return 0;
}
```

Quiz ?

What is the output of the program below:

```
#include <stdio.h>
void swap(int a, int b);
int main(void){
    int i = 1, j = 2;
    swap(i, j);
    printf("i = %d, j = %d\n", i, j);
    return 0;
}

void swap(int a, int b){
    int temp = a;
    a = b;
    b = temp;
}
```




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Today's Summary

- Nested Loops 
- Modular Programming through Functions 
- Recursion 

Next up 

Dr Bo Liu

- Functions continued
- Arrays



Questions ?

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Further Reading

- An awesome  online book 
- Lets you practice coding on site

