FUNCTIONS

CS10003: PROGRAMMING AND DATA STRUCTURES

Introduction

Function

- A program segment that carries out a specific, well-defined task.
  - Example
    - A function to add two numbers
    - A function to find the largest of n numbers
- A function will carry out its intended task whenever it is called
  - Functions may call other functions (or itself)
  - A function can be called multiple times

- Every C program consists of one or more functions.
    - One of these functions must be called "*`main`*".
    - Execution of the program always begins by carrying out the instructions in "*`main`*".

Function Control Flow

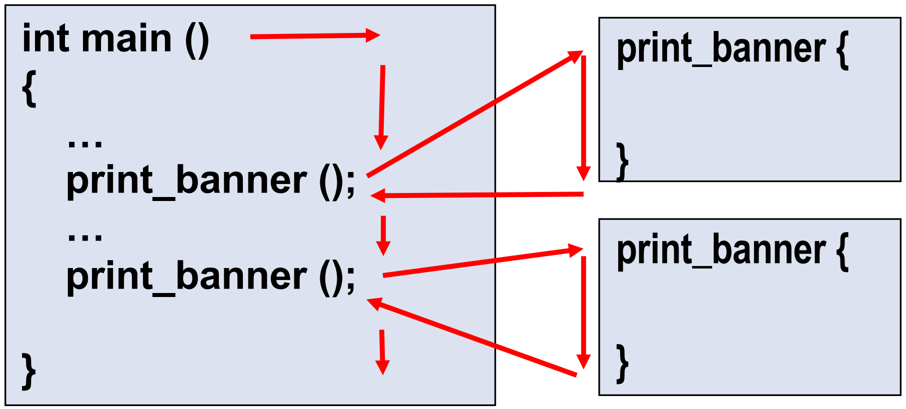
Code

```
void print_banner ( )
{
      printf("***********\n");
}
```

```
int main ( )
{
    . . .
    print_banner ( ) ;
    . . .
    print_banner ( ) ;

}
```

Execution



If function A calls function B:
A → calling function / caller function
B → called function

Why Functions?

Functions allow one to develop a program in a modular fashion.

- Divide-and-conquer approach.

Use existing functions as building blocks for new programs → minimize effort in writing long programs

Abstraction: hide internal details (library functions)

Use of functions: *Area of a circle*

```
#include <stdio.h>

/* Function to compute the area of a circle */
float   myfunc (float r)
{            float   a;
             a = 3.14159 * r * r;
             return (a);     /* return result */
}
main()
{       float   radius, area;
        float   myfunc (float);

        scanf ("%f", &radius);
        area = myfunc (radius);
        printf ("\n Area is %f \n", area);
}
```

Function definition

Function argument

Function declaration / prototype
(only states the type of input and output)

Function call

Use of functions: *Area of a circle*

```
#include <stdio.h>

/* Function to compute the area of a circle */
float   myfunc (float r)
{               float   a;
                a = 3.14159 * r * r;
                return (a);      /* return result */
}
main()
{       float   radius, area;
        float   myfunc (float);

        scanf ("%f", &radius);
        area = myfunc (radius);
        printf ("\n Area is %f \n", area);
}
```

Function definition

Function argument

Function call

- A called function processes information that is passed to it from the calling function, and the called function may return a single value (result) to the calling function.
  - Information passed to the function via special identifiers called *arguments* or *parameters*.
  - The value is returned by the "`return`" statement.

Defining a Function

A function definition has two parts:

- The first line
- The body of the function

General syntax:

return-value-type function-name (*parameter-list*)

{

declarations and statements

}

The first line contains the return-value-type, the function name, and optionally a set of comma-separated arguments enclosed in ( ).

- Each argument has an associated type declaration.
- The arguments are called *formal arguments* or *formal parameters*.

Example:

float myfunc (float r)

int gcd (int A, int B)

return value type

```
#include <stdio.h>

/* Function to compute the area of a circle */
float   myfunc (float r)
{           float   a;
            a = 3.14159 * r * r;
            return (a);
}

main()
{      float   radius, area;
       float   myfunc (float);

       scanf ("%f", &radius);
       area = myfunc (radius);
       printf ("\n Area is %f \n", area);
}
```

Calling a function

- Called by specifying the function name and parameters in an instruction in the calling function

- When a function is called from some other function, the corresponding arguments in the function call are called actual arguments or actual parameters
  - The function call must include a matching actual parameter for each formal parameter
  - Position of an actual parameters in the parameter list in the call must match the position of the corresponding formal parameter in the function definition
  - The formal and actual arguments must match in their data types

```
#include <stdio.h>


/* Function to compute the area of a circle */
float   myfunc (float r)
{               float   a;
                a = 3.14159 * r * r;
                return (a);
}

main()
{       float   radius, area;
        float   myfunc (float);

        scanf ("%f", &radius);
        area = myfunc (radius);
        printf ("\n Area is %f \n", area);
}
```

Function Prototypes: declaring a function

Usually, a function is defined before it is called

- main() is the last function in the program written
- Easy for the compiler to identify function definitions in a single scan through the file

However, many programmers prefer a top-down approach, where the functions are written after main()

- Must be some way to tell the compiler what is a function when compilation reaches a function call
- Function prototypes are used for this purpose
    - Only needed if function definition comes after a call to that function

- Function prototypes are usually written at the beginning of a program, ahead of any functions (including main())
- Prototypes can specify parameter names or just types (more common)
- Examples:

```
int  gcd (int , int );
void div7 (int number);
```

- Note the semicolon at the end of the line.
- The parameter name, if specified, can be anything; but it is a good practice to use the same names as in the function definition

Example:

Function prototype / declaration

```
#include <stdio.h>
int sum( int, int );
int main( )
{
        int x, y;
        scanf("%d%d", &x, &y);
        printf("Sum = %d\n", sum(x, y));
}
int sum (int a, int b)
{
        return(a + b);
}
```

Function call

Function definition

This program needs a function prototype or function declaration since

The function call comes before the function definition

Return value

- A function can return a single value
  - Using return statement
- Like all values in C, a function return value has a type
- The return value can be assigned to a variable in the calling function

```
int main( )
{
        int x, y, s;
        scanf("%d%d", &x, &y);
        s = sum(x, y);
}
int sum (int a, int b)
{
        return(a + b);
}
```

- Sometimes a function may not return anything
- Such functions are of type void

Example: A function which prints if a number is divisible by 7 or not

```
void  div7 (int n)
{
   if  ((n % 7) == 0)
          printf ("%d is divisible by 7", n);
   else
          printf ("%d is not divisible by 7", n);
   return;
}
```

- The return type is void
- The return statement for void functions is optional

The return statement

In a value-returning function, return does two distinct things:

- specify the value returned by the execution of the function
- terminate that execution of the called function and transfer control back to the caller function

A function can only return one value

- The value can be any expression matching the return type
- but it might contain more than one return statement.

In a void function

- return is optional at the end of the function body.
- return may also be used to terminate execution of the function explicitly before reaching the end.
- No return value should appear following return.

```
void compute_and_print_itax ()
{
    float income;
    scanf (“%f”, &income);
    if (income < 50000)   {
                printf (“Income tax = Nil\n”);
                return;  /* Terminates function execution */
    }
    if (income < 60000)   {
                printf (“Income tax = %f\n”, 0.1*(income-50000));
                return;  /* Terminates function execution */
    }
    if (income < 150000) {
                 printf (“Income tax = %f\n”, 0.2*(income-60000)+1000);
                return ; /* Terminates function execution */
    }
    printf (“Income tax = %f\n”, 0.3*(income-150000)+19000);
}
```

Another Example: What is happening here?

```
int main()
{
  int numb, flag, j=3;
  scanf("%d",&numb);
   while (j <= numb)
   {
       flag = prime( j );
       if (flag==0)  printf( "%d is prime\n", j );
       j++;
   }
   return 0;
 }
```

```
int prime(int x)
{
   int i, test;
   i=2, test =0;
   while ((i <= sqrt(x)) && (test ==0))
   {
       if (x%i==0) test = 1;
       i++;
     }
    return test;
}
```

Tracking the flow of control

```c
int main()
{
  int numb, flag, j=3;
  scanf("%d",&numb);
  printf("numb = %d \n",numb);
  while (j <= numb)
  {
    printf("\nMain, j = %d\n",j);
    flag = prime(j);
    printf("Main, flag = %d\n",flag);

    if (flag == 0) printf("%d is prime\n",j);
    j++;
  }
  return 0;
}
```

```c
int prime(int x)
{
   int i, test;
   i = 2;  test = 0;

   printf("In function, x = %d \n",x);
   while ((i <= sqrt(x)) && (test == 0))
   {
      if (x%i == 0) test = 1;
      i++;
   }
   printf("Returning, test = %d \n",test);

   return test;
}
```

PROGRAM OUTPUT

```
5
numb = 5

Main, j = 3
In function, x = 3
Returning, test = 0
Main, flag = 0
3 is prime

Main, j = 4
In function, x = 4
Returning, test = 1
Main, flag = 1

Main, j = 5
In function, x = 5
Returning, test = 0
Main, flag = 0
5 is prime
```

Nested Functions

A function cannot be defined within another function. It can be called within another function.

- All function definitions must be disjoint.

Nested function calls are allowed.

- A calls B, B calls C, C calls D, etc.
- The function called last will be the first to return.

A function can also call itself, either directly or in a cycle.

- A calls B, B calls C, C calls back A.
- Called *recursive call* or *recursion*.

Example: main( ) calls ncr( ), ncr( ) calls fact( )

```
#include  <stdio.h>

int ncr (int n, int r);
int fact (int n);

main()
{
        int i, m, n, sum=0;
        scanf ("%d %d", &m, &n);

        for (i=1; i<=m; i+=2)
           sum = sum + ncr(n, i) ;

        printf ("Result: %d \n", sum);
}
```

```
int  ncr (int n, int r)
{
        return (fact(n) / fact(r) / fact(n-r));
}


int  fact (int n)
{
        int  i, temp=1;
        for (i=1; i<=n; i++) temp *= i;
        return (temp);
}
```

Local variables

A function can define its own local variables

The local variables are known (can be accessed) only within the function in which they are declared

- Local variables cease to exist when the function returns
- Each execution of the function uses a new set of locals

Parameters are also local

```
/* Find the area of a circle with diameter d */
double circle_area (double d)
{
        double radius, area;
        radius = d/2.0;
        area = 3.14*radius*radius;
        return (area);
}
```

parameter

local variables

Revisiting nCr

```
int  ncr (int n, int r)
{
        return (fact(n) / fact(r) / fact(n-r));
}

int  fact (int n)
{
        int  i, temp=1;
        for (i=1; i<=n; i++) temp *= i;
        return (temp);
}
```

The n in ncr( ) and the n in fact( ) are different

Scope of a variable

- Part of the program from which the value of the variable can be used (seen)

- Scope of a variable - Within the block in which the variable is defined
  - Block = group of statements enclosed within { }

- Local variable – scope is usually the function in which it is defined
  - So two local variables of two functions can have the same name, but they are different variables

- Global variables – declared outside all functions (even main)
  - scope is entire program by default, but can be hidden in a block if local variable of same name defined

What happens here?

Scope of global A

```
#include <stdio.h>
int A;   /* This A is a global variable */
void main( )
{
    A = 1;
    myProc( );
    printf ( "A = %d\n", A );
}

void myProc( )
{
    A = 2;

    /* other statements */



    printf ( "A = %d\n", A );
}
```

A = 2

A = 2

Local Scope replaces Global Scope

```
#include  <stdio.h>
int A;   /* This A is a global variable */
void main( )
{
    A = 1;
    myProc( );
    printf ( "A = %d\n", A );
}

void myProc( )
{
    int A = 2;  /* This A is a local variable */

    /* other statements */
    /* within this function, A refers to the local A */

    printf ( "A = %d\n", A );
}
```

A = 1

A = 2

Scope of global A

Scope of local A

Parameter Passing

When the function is called, the value of the actual parameter is copied to the formal parameter

parameter passing

```
int main ()
{           . . .
            double radius, a;
            . . .
            a = area(radius);
            . . .
}
```

```
double area (double r)
{
            return (3.14*r*r);
}
```

Parameter Passing by Value in C

- Used when invoking functions

Call by value / parameter passing by value

- Called function gets a copy of the value of the actual argument passed to the function
- Execution of the function does not change the actual arguments
    - All changes to a parameter done inside the function are done on the copy
    - The copy is removed when the control returns to the caller function
    - The value of the actual parameter in the caller function is not affected
- Avoids accidental changes

Call by reference – not supported in C, but supported in some other languages like C++

- Passes the address *of* the original argument to a called function.
- Execution of the function may affect the original argument in the calling function

Parameter passing & return: 1

```
int main()
{
    int  a=10, b;
    printf  ("Initially a = %d\n", a);
    b = change (a);
    printf  ("a = %d, b = %d\n", a, b);
    return 0;
}
int  change  (int x)
{
   printf  ("Before x = %d\n",x);
    x = x / 2;
   printf  ("After x = %d\n", x);
    return (x);
}
```

Output

```
Initially a = 10
Before x = 10
After x = 5
a = 10, b = 5
```

Parameter passing & return: 2

```
int main()
{
    int  x=10, b;
    printf  (“M: Initially x = %d\n”, x);
    b = change (x);
    printf  (“M: x = %d, b = %d\n”, x, b);
    return 0;
}
int  change  (int x)
{
   printf  (“F: Before x = %d\n”,x);
    x = x / 2;
   printf  (“F: After x = %d\n”, x);
    return (x);
}
```

Output

```
M: Initially x = 10
F: Before x = 10
F: After x = 5
M: x = 10, b = 5
```

Parameter passing & return: 3

```
int main()
{
   int  x=10, y=5;
   printf  (“M1:  x = %d, y = %d\n”, x, y);
   interchange (x, y);
   printf  (“M2:  x = %d, y = %d\n”, x, y);
   return 0;
}

void interchange  (int x, int y)
{ int temp;
  printf  (“F1:  x = %d, y = %d\n”, x, y);
  temp= x; x = y; y = temp;
  printf  (“F2:  x = %d, y = %d\n”, x, y);
}
```

Output

```
M1:  x = 10, y = 5
F1:  x = 10, y = 5
F2:  x = 5, y = 10
M2:  x = 10, y = 5
```

How do we write an interchange function?
(will see later)

Header files and preprocessor

Header Files

Header files

- Contain function declarations / prototypes for library functions.
- `<stdlib.h>` , `<math.h>` , etc
- Load with: `#include <filename>`
- Example : `#include <math.h>`
- The function definitions of library functions are in the actual libraries (e.g., math library)

We can also create custom header files

- Create file(s) with function prototypes / declarations.
- Save as `filename.h` (say).
- Load in other files with `#include "filename.h"`

C preprocessor

- Statements starting with # are handled by the C preprocessor
- A module that processes the program before the actual compilation
- Is NOT a part of the C compiler

- The C preprocessor is basically a text substitution tool
- For instance, #include command is replaced by the contents of the specified header file
- Such commands are called preprocessor directives

- We will study one more preprocessor directives -- #define
- There are more such directives – see book

#define: Macro definition

Preprocessor directive in the following form:

```
#define  string1  string2
```

- Replaces string1 by string2 wherever it occurs before compilation. For example,

```
#define  PI  3.1415926
```

```
#include <stdio.h>
#define PI 3.1415926
main()
{
  float r = 4.0, area;
  area = PI * r * r;
}
```

macro pre-processing →

```
#include <stdio.h>
main()
{
  float r = 4.0, area;
  area = 3.1415926 * r * r;
}
```

#define with arguments

#define statement may be used with arguments.

- Example: #define sqr(x) x*x
- How will macro substitution be carried out?

```
r = sqr(a) + sqr(30);    →    r = a*a + 30*30;
r = sqr(a+b);            →    r = a+b*a+b;
```

WRONG?

- The macro definition should have been written as:

```
#define sqr(x) (x)*(x)
r = sqr(a+b);            →    r = (a+b)*(a+b);
```

Storage Class of Variables

What is Storage Class?

It refers to the permanence / lifetime of a variable, and its *scope* within a program.

Scope of a variable – from which parts of a program can the variable be accessed

Permanence / lifetime – during execution of the program, for how long the variable exists in the memory

Four storage class specifications in C:

- Automatic: `auto`
- External : `extern`
- Static : `static`
- Register : `register`

Automatic Variables

These are always declared within a function and are local to the function in which they are declared.

- Scope is confined to that function.

This is the default storage class specification.

- All variables are considered as `auto` unless explicitly specified otherwise.
- The keyword `auto` is optional.
- An automatic variable does not retain its value once control is transferred out of its defining function.

```
#include <stdio.h>
int factorial( int m )
{
     auto int i;
     auto int temp=1;
     for ( i=1; i<=m; i++ )
               temp = temp * i;
     return ( temp );
}
```

```
main()
{
     auto int  n;
     for (n=1; n<=10; n++)
    printf ( “%d! = %d \n”,  n, factorial (n) );
}
```

Static Variables

Static variables are defined within individual functions and have the same scope as automatic variables.

Unlike automatic variables, static variables retain their values throughout the life of the program.

- If a function is exited and re-entered at a later time, the static variables defined within that function will retain their previous values.
- Initial values can be included in the static variable declaration.
    - Will be initialized only once.

Static Variables

Initialization will happen only the first time the function is called

```
void test( int x )
{
    static int count = 0;

    if ( x == 0 ) {
            if ( count == 2 ) {
               printf ("Three consecutive zeros");
            }
            else count++;
    }
    else count = 0;
    return;
}
```

```
main( )
{
    int k, marks;

    for ( k=0;  k < 100; k++ )
    {
            scanf("%d", &marks) ;
            test( marks );
    }
}
```

Function that detects three consecutive zeroes in a stream of 100 marks.

Register Variables

These variables are stored in high-speed registers (memory elements within the CPU).

- Commonly used variables may be declared as register variables.
- Results in increase in execution speed.
- The final allocation is decided by the compiler; not guaranteed that all register variables will actually be stored.

For example:

```
register int y;  // Instructs the compiler to allocate some register to y
```

External Variables

They are not confined to single files.

Their scope extends from the point of definition through the remainder of the program.

- They may span more than one file.
- They too are global variables.

Informs the compiler that k is an integer variable but space is not to be allocated for it.

FILE a.c

```
extern int k;
void f ( void )
{
    k++;
 }
```

FILE b.c

```
int k=0;
extern void f ( void );
void g ( void )
{
    f( );
    printf( "%d\n", k );
 }
```

Practice Problems

No separate problems needed.

- Look at everything that you did so far, such as finding sum, finding average, counting something, checking if something is true or false (" Is there an element in array A such that….) etc. in which the final answer is one thing only (like sum, count, 0 or 1,…).
- Then for each of them, rather than doing it inside main (as you have done so far), write it as a function with appropriate parameters, and call from main() to find and print.

  - Normally, read and print everything from main(). Do not read or print anything inside the function. This will give you better practice.
  - However, you can write simple functions for printing an array.