FUNCTIONS

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Introduction

Structured Programming is a problem-solving strategy and a programming methodology that includes the following two guidelines:

- The flow of control in a program should be as simple as possible.
- The construction of a program should embody top-down design.

Top-down Design

Top-down design, *stepwise refinement*, or *divide and conquer*

- consists of repeatedly decomposing a problem into smaller problems.
  - i.e., construct a program from smaller pieces (components, modules)
- Each piece more manageable than the original program
- Create new primitives

Functions

- Functions
  - Programs combine user-defined functions with library functions
    - C standard library has a wide variety of functions
- Function calls
  - Invoking functions
    - Provide function name and arguments (data)
    - Function performs operations or manipulations
    - Function returns results
  - Function call analogy:
    - Boss asks worker to complete task
      - Worker gets information, does task, returns result
      - Information hiding: boss does not know details

Functions

- We have already written our own functions and used library functions:
  - `main` is a function that must exist in every C program.
  - `printf`, `scanf` are library functions which we have already used in our programs.
- We need to do two things with functions:
  - create functions
  - call functions (Function invocation)

Function Definition

A function definition has the following form:

```
return_type  function_name  (parameter-declarations)
{
        variable-declarations

        function-statements
}
```

return_type - specifies the type of the function and corresponds to the type of value returned by the function

- `void` – indicates that the function returns nothing.
- if not specified, of type `int`

function_name – name of the function being defined (any valid identifier)

parameter-declarations – specify the types and names of the parameters (a.k.a. formal parameters) of the function, separated by commas.

Example: Function returning a value

- Let's define a function to compute the cube of a number:

```
int cube ( int num ) {
            int result;

      result = num * num * num;
      return result;
 }
```

- This function can be called as:

```
n = cube(5);
```

Example: void Function

```
void prn_message(void) /* function definition */
{
      printf("A message for you:   ");
      printf("Have a nice day!\n");
}


int main (void)
{
     prn_message ( );      /* function invocation */
     return 0;
}
```

Math Library Functions

- Math library functions
  - perform common mathematical calculations
  - `#include <math.h>`

- Format for calling functions
  - `FunctionName(` *argument* `);`
    - If multiple arguments, use comma-separated list
  - `y = sqrt( 900.0 );`
    - Calls function `sqrt`, which returns the square root of its argument
  - Arguments may be any r-value (constants, variables, or expressions)

Math Library Functions

Function Header	Description
int abs(int num)	Returns the absolute value of an integer element.
double fabs(double num)	Returns the absolute value of a double precision element.
double pow(double x,double y)	Returns x raised to the power of y.
int rand(void)	returns a random number
double sin(double angle)	Returns the sine of an angle; the angle should be in Radius.
double cos(double angle)	Returns the cosine of an angle; the angle should be in Radius.
double sqrt(double num)	Returns the the square root of a double

Math Library Functions

- Calculate the square root of $(x1 - x2)^2 + (y1 - y2)^2$

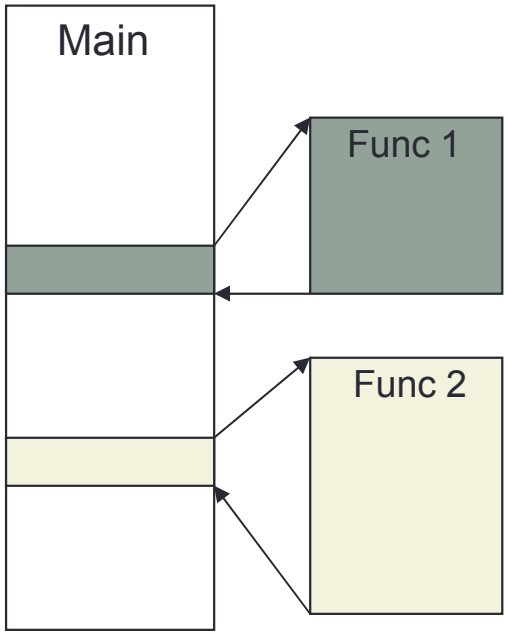
```
a = x1 - x2;
b = y1 - y2;
c = pow(a,2) + pow(b, 2);
d = sqrt(d);
```

General Structure of a C Program

```
preprocessor directives

function prototypes

int main () {
.
.
.
}

function-1
function-2
.
.
.
function-n
```

Function Invocation

- A program is made up of one or more functions, one of them being `main( )`.
- When a program encounters a function, the function is called or invoked.
- After the function does its work, program control is passed back to the calling environment, where program execution continues.



Variable Declarations within Function Definitions

- Variables declared local to a function supersede any identically named variables outside the function

```
int lcm(int m, int n) {
    int i;
    ...
}

int gcd(int m, int n) {
    int i;
    ...
}
```

The `return` statement

- When a return statement is executed, the execution of the function is terminated and the program control is immediately passed back to the calling environment.

- If an expression follows the keyword return, the value of the expression is returned to the calling environment as well.

- A return statement can be one of the following two forms:

```
return;
return expression;
```

Examples

```
return;

return 1.5;

return result;

return a+b*c;

return x < y ? x : y;
```

Example

```
int IsLeapYear(int year)
{
   return ( ((year % 4 == 0) && (year % 100 != 0))
            || (year % 400 == 0) );
}
```

- This function may be called as:

```
if (IsLeapYear(2005))
   printf("29 days in February.\n");
else
   printf("28 days in February.\n");
```

Example

```
#include  <stdio.h>
int min(int a, int b)
{
   if (a < b)
      return a;
   else
      return b;
}

int main (void)
{
   int j, k, m;

   printf("Input two integers:    ");
   scanf("%d %d", &j, &k);
   m = min(j,k);
   printf("\nThe minimum is %d.\n", m);
   return 0;
}
```

```
Input two integers:  5  6
The minimum is 5.

Input two integers:  11  3
The mininum is 3.
```

Parameters

- A function can have zero or more parameters.
- In declaration header:

```
int f (int x, double y, char c);
```

the *formal parameter list*
(parameter variables and
their types are declared here)

- In function calling:

```
value = f(age, 100*score, initial);
```

actual parameter list
(cannot tell what their type are from here)

r-value

Rules for Parameter Lists

- The number of parameters in the actual and formal parameter lists must be *consistent*
- Parameter association is *positional:* the first *actual* parameter matches the first *formal* parameter, the second matches the second, and so on
- *Actual* parameters and *formal* parameters must be of compatible *data types*
- *Actual* parameters may be a variable, constant, any expression matching the type of the corresponding formal parameter

Invocation and Call-by-Value

- Each argument is evaluated, and its value is used locally in place of the corresponding formal parameter.
- If a variable is passed to a function, the stored value of that variable in the calling environment will not be changed.
- In C, all calls are call-by-value unless specified otherwise.

Function Call

- The type of a function-call expression is the same as the type function being called, and its value is the value returned by the function.
- Function calls can be embedded in other function calls.
  - **e.g.**

```
t = cubesum(i);
j = cubesum(t);
```

is equivalent to

```
j = cubesum(cubesum(i));
```

Example

```
#include  <stdio.h>

int compute_sum (int n)
{
   int  sum;

   sum = 0;

   for (  ; n > 0; --n)
      sum += n;
   printf("%d\n", n);
   return sum;
}
```

```
int main (void)
{
   int n, sum;

   n = 3;

   printf("%d\n", n);
   sum=compute_sum(n);
   printf("%d\n",n);
   printf("%d\n", sum);
   return 0;
}
```

```
3
0
3
6
```

Example

```
/* Finding the maximum of three integers */

#include <stdio.h>

/* Function maximum definition */
int maximum( int x, int y, int z )
{
   int max = x;

   if ( y > max )
      max = y;

   if ( z > max )
      max = z;

   return max;
}

int main()
{
   int a, b, c;

   printf( "Enter three integers: " );
   scanf( "%d%d%d", &a, &b, &c );
   printf( "Maximum is: %d\n", maximum( a, b, c ) );

   return 0;
}
```

```
Enter three integers: 22 85 17
Maximum is: 85
```

Function Call

- ANSI-C does not set the arguments evaluation order in function calls
  - **e.g.**

```
x = 7; a = 2.25;
```

```
f(x=6, x-7, a)
   ↓    ↓   ↓
   6   -1  2.25
```

```
f(x=6, x-7, a)
   ↓    ↓   ↓
   6    0  2.25
```

```
printf("%d %d%, i, i++);
printf("%d %d%, i, ++i);
```

ambiguous

Function Prototypes

- General form for a function prototype declaration:

  return_type function_name (parameter-type-list)

- Used to validate functions
  - Prototype only needed if function definition comes after use in program

- The function with the prototype

  ```
  int maximum( int, int, int );
  ```

  - Takes in 3 `int`s
  - Returns an `int`

Alternative styles for function definition order

```c
#include <stdio.h>

int max(int,int);
int min(int,int);

int main(void)
{
  min(x,y);
  max(u,v);
  ...
}
int max (int a, int b)
{
  ...
}
int min (int a, int b)
{
 ...
}
```

```c
#include <stdio.h>
int max (int a, int b)
{
  ...
}

int min (int a, int b)
{
  ...
}

int main(void)
{
  ...
  min(x,y);
  max(u,v);
  ...
}
```

Block Structure

- A block is a sequence of variable declarations and statements enclosed within braces.
- Block structure and the scope of a variable

```
int factorial(int n)
  {
     if (n<0) return -1;
     else if (n==0) return 1;
     else
     {
        int i, result=1;
        for (i=1;i<=n; i++) result *= i;
        return result;
     }
   }
```

External Variables

- Local variables can only be accessed in the function in which they are defined.

- If a variable is defined outside any function at the same level as function definitions, it is available to all the functions defined below in the same source file

  → external variable

- **Global variables:** external variables defined before any function definition
  - Their scope will be the whole program

Example

```
#include   <stdio.h>
void print_message (int k);    /*function prototype */

int main (void)
{
      int n;

      printf("There is a message for you.\n");
      printf("How many times do you want to see it?  ");
      scanf("%d", &n);
      print_message(n);
      return 0;
}

void print_message (int k)  /* function definition */
{
      int i;

      printf("\nHere is the message.\n");
      for (i=0; i < k; ++i)
            printf("Have a nice day!\n");
}
```

Example

```
/* An example demonstrating local variables */
#include  <stdio.h>

void func1 (void);

int main (void)
{
      int i = 5;
      printf("%d \n", i);
      func1( );
      printf("%d \n",i);
      return 0;
}

void func1 (void)
{
       int i = 5;
       printf("%d\n", i);
       i++;
        printf("%d\n", i);
}
```

```
5
5
6
5
```

Example: Transforming rectangular coordinates to polar coordinates

```
#include <math.h>
#include <stdio.h>
#define PI 3.1415927

float r, theta;
void polar (float x, float y)

int main(void){
  float x, y;
  scanf("%f %f", &x, &y);
  polar(x,y);
  printf("r = %f, theta = %f\n", r, theta);
  return 0;
}

void polar(float x, float y)
{
   if (x==0 && y==0) r = theta = 0;
   else {
      r = sqrt(x*x + y*y);
      theta = atan2(y,x); }
}
```

Static Variables

- A variable is said to be static if it is allocated storage at the beginning of the program execution and the storage remains allocated until the program execution terminates.
- External variables are always static

- Within a block, a variable can be specified to be static by using the keyword static before its type declaration:

  `static` type variable-name;

- Variable declared static can be initialized only with constant expressions (if not, its default value is zero)

Example

```
#include <stdio.h>
void incr(void);

int main(void)
{
   int i;
   void incr(void);

   for (i=0; i<3; i++)
         incr();
   return 0;
}

void incr(void)
{
   static int static_i=0;
   printf("static_i = %d\n", static_i++);
}
```

Output:

```
static_i = 0
static_i = 1
static_i = 2
```

Example

```
#include <stdio.h>

put_stars(int n)
{
  static int eski_n;
  int i;
  for (i=0;i<eski_n;i++)
        printf(" ");
  for (i=0;i<n;i++)
        printf("*");
  printf("\n");
  eski_n += n;
}

int main(void)
{
   put_stars(3); put_stars(2); put_stars(3);
   return 0;
}
```

Output:

```
***
   **
     ***
```

Correct the errors in the following program segments

1.
```
int g (void) {
        printf (“Inside function g\n”);

        int h(void) {
           printf(“Inside function h\n”);
        }
  }
```

2.
```
int sum(int x, int y) {
          int result;
          result = x + y;
      }
```

Correct the errors in the following program segments

3.
```
void f (float a); {
        float a;
        printf ("%f", a); }
```

4.
```
void product (void) {
         int a, b, c, result;
         printf("Enter 3 integers: ");
         scanf("%d %d %d", &a, &b, &c);
         result = a * b * c;
         printf("Result is %d\n", result);
         return result;
 }
```

Exercises

- Define a function to calculate
  $(x^2 + y^2 + z^2)^{1/2}$
  and use it to calculate

  $a = 1/(u^2+v^2+w^2)^{1/2}$, $b = (u^4 + v^4 + w^4)^{1/2}$,
  $g = (4u^2+9v^2+25w^2)^{1/2}$, $h = (3u^2)^{1/2}(12v^2)^{1/2}(27w^2)^{1/2}$

Exercises

- Analyze the output of the following program

```
#include <stdio.h>
int i=0;

void f(void)
{
  int i;
  i = 1;
}
void g(void)
{
  i=2;
}
void h(int i)
{
  i=3;
}
```

```
int main(void)
{
  {
    int i=4;
    printf("%d\n", i);
  }
  printf("%d\n", i);
  f();
  printf("%d\n", i);
  g();
  printf("%d\n", i);
  h(i);
  printf("%d\n", i);
  return 0;
}
```

Programming Exercise

- Write a program that that reads in the side of a square and then prints a hollow square. Your program should work for squares of all side sizes between 1 and 20. For example, if your program reads a size of 4, it should print:

```
****
*  *
*  *
****
```

Programming Exercise

- Twin primes are defined to be two consecutive odd numbers which are both primes. For example, 11 and 13 are twin primes. Write a program to generate all the twin primes in a given range of numbers.