

COMP9024: Data Structures and Algorithms

Week 1: Introduction to C

1

Contents

- Basic Structure of a C Program
- Assignments
- Conditionals
- Loops
- Functions
- Basic Data Types
- Arrays
- Strings
- Functions
- Structures
- Basic I/O

2

Brief History of C

- C and UNIX operating system share a complex history
- C was originally designed for and implemented on UNIX on a PDP-11 computer
- Dennis Ritchie was the author of C (around 1971)
- In 1973, UNIX was rewritten in C by Ken Thompson and Dennis Ritchie
- B (author: Ken Thompson, 1970) was the predecessor to C, but there was no A

3

Basic Structure of a C Program

```
// include files
// global definitions
// function definitions
function_type function_name(arguments) {
    // local variables
    // body of function
    ...
    return;
}
...

// main function
int main(arguments)
// local variables
// body of main function
...
    return 0;
}
```

4

Example 1: Insertion Sort in C

```
#include <stdio.h>
#define SIZE 6

void insertionSort(int array[], int n) {
    int i;
    for (i = 1; i < n; i++) {
        int element = array[i];          // for this element ...
        int j = i-1;
        while (j >= 0 && array[j] > element) { // ... work
            down the ordered list
            array[j+1] = array[j];        // ... moving elements
            up
            j--;
        }
        array[j+1] = element;            // and insert in
        correct position
    }
}

int main(void) {
    int numbers[SIZE] = { 3, 6, 5, 2, 4, 1 };
    int i;

    insertionSort(numbers, SIZE);
    for (i = 0; i < SIZE; i++)
        printf("%d\n", numbers[i]);

    return 0;
}
```

5

Example 2: Computing Greatest Common Divisor

```
#include <stdio.h>

int f(int m, int n) { /* compute the greatest common divisor of m and n */
    while (m != n) {
        if (m > n)
            m = m-n;
        else
            n = n-m;
    }
    return m;
}

int main(void) {
    printf("%d\n", f(30,18));
    return 0;
}
```

6

Compiling with gcc

- C source code: prog.c
 ↓
 a.out (executable program)
- To compile a program prog.c, type the following command:
 prompt\$ gcc prog.c
- To run the program, type:
 prompt\$./a.out

7

Basic Elements

- Assignments
- Conditionals
- Loops
- Function calls/return statements

8

Assignments

- In C, each statement is terminated by a semicolon ;
- Curly brackets { } used to enclose statements in a block
- The operators ++ and -- can be used to increment a variable (add 1) or decrement a variable (subtract 1)
- It is recommended to put the increment or decrement operator after the variable:
// suppose k=6 initially
k++; // increment k by 1; afterwards, k=7
n = k--; // first assign k to n, then decrement k by 1
// afterwards, k=6 but n=7
- It is also possible (but NOT recommended) to put the operator before the variable:
// again, suppose k=6 initially
++k; // increment k by 1; afterwards, k=7
n = --k; // first decrement k by 1, then assign k to n

9

Conditionals

```
if (expression) {  
    some statements;  
}
```

```
if (expression) {  
    some statements1;  
} else {  
    some statements2;  
}
```

- Some statements executed if, and only if, the evaluation of expression is non-zero
- Some statements1 executed when the evaluation of expression is non-zero
- Some statements2 executed when the evaluation of expression is zero
- Statements can be single instructions or blocks enclosed in { }

10

Printing Variable Values with printf()

- Formatted output written to standard output (e.g. screen)

```
printf(format-string, expr1, expr2, ...);
```

- format-string can use the following placeholders:

%d	decimal	%f	floating point number
%c	character	%s	string
\n	new line	\"	quotation mark

Examples:

```
num = 3;
printf("The cube of %d is %d.\n", num, num*num*num);
// Output: The cube of 3 is 27.
char id = 'z';
int num = 1234567;
printf("Your \"login ID\" will be in the form of %c%d.\n", id, num);
// Output: Your "login ID" will be in the form of z1234567.
```

- Can also use width and precision:

```
printf("%.3f\n", 3.14159);
// Output is 3.142
```

11

Loops

- C has two different "while loop" constructs

```
// while loop
while (expression) {
    some statements;
}
```

```
// do .. while loop
do {
    some statements;
} while (expression);
```

- The do .. while loop ensures the statements will be executed at least once

12

Functions (1/2)

- Functions have the form

```
return-type function-name(parameters) {  
    declarations  
    statements  
    return;  
}
```

- if `return_type` is void, the function does not return a value
- if `parameters` are void, the function has no arguments
- Parameter passing
 - Pass by value for scalar variables
 - Pass by reference for structures and arrays

13

Functions (2/2)

```
#include <stdio.h>  
int gcd(int m, int n);  
int main()  
{  
    int m, n;  
    printf("Enter two positive integers: ");  
    scanf("%d %d", &m, &n);  
  
    printf("The greatest common divisor of %d and %d is %d.", m, n, gcd(m,n));  
    return 0;  
}  
  
int gcd(int m, int n) // compute the GCD of two positive integers  
{  
    if (n != 0)  
        return gcd(n, m%n);  
    else  
        return m;  
}
```

14

C Style Guide

- UNSW Computing provides a style guide for C programs:
- C Coding Style Guide
(<http://wiki.cse.unsw.edu.au/info/CoreCourses/StyleGuide>)
- Not mandatory for COMP9024, but very useful guideline
- Use proper layout, including indentation
- Keep functions short and break into sub-functions as required
- Use meaningful names (for variables, functions etc)

15

Basic Data Types (1/2)

- In C each variable must have a type
- C has the following generic data types:

<code>char</code>	character	'A', 'e', '#', ...	// Characters are encoded using ASCII code
<code>int</code>	integer	2, 17, -5, ...	// 32 bits
<code>float</code>	32 bit single precision floating-point number		3.14159, ...
<code>double</code>	64 bit double precision floating-point		3.14159265358979, ...
- There are other types, which are variations on these
- Variable declaration must specify a data type and a name; they can be initialised when they are declared:

```
float x;  
char ch = 'A';  
int j = 10;
```

A complete list is available at https://en.wikipedia.org/wiki/C_data_types

16

Symbolic Constants

- We can define a symbolic constant at the top of the file
`#define SPEED_OF_LIGHT 299792458.0`
- Symbolic constants used to avoid burying "magic numbers" in the code
- Symbolic constants make the code easier to understand and maintain
`#define name replacement_text`
- The compiler's pre-processor will replace all occurrences of **name** with **replacement_text**. It will not make the replacement if name is inside quotes ("...") or part of another name
- Example: The constants TRUE and FALSE are often used when a condition with logical value is wanted. They can be defined by:
`#define TRUE 1`
`#define FALSE 0`

17

Aggregate Data Types

- Families of aggregate data types:
 - homogenous ... all elements have same base type
 - arrays (e.g. char s[50], int v[100])
 - heterogeneous ... elements may combine different base types
 - structures

18

Arrays

- An array is a collection of same-type variables arranged as a linear sequence accessed using an integer subscript
- For an array of size N, valid subscripts are 0..N-1
- Examples:

```
int a[20]; // array of 20 integer values/variables
```

```
char b[10]; // array of 10 character values/variables
```

19

Strings

- "String" is a special word for an array of characters
- end-of-string is denoted by '\0' (of type char and always implemented as 0)
- Example:

If a character array s[11] contains the string "hello", this is how it would look in memory:

```
0 1 2 3 4 5 6 7 8 9 10
-----
| h | e | l | l | o | \0 |   |   |   |   |
-----
```

- Characters are encoded using ASCII code

20

Array Initialisation

- Arrays can be initialised by code, or you can specify an initial set of values in declaration.
- Examples:

```
char s[6] = {'h', 'e', 'l', 'l', 'o', '\0'};  
char t[6] = "hello";  
int fib[20] = {1, 1};  
int vec[] = {5, 4, 3, 2, 1};
```

In the third case, `fib[0] = fib[1] = 1` while the initial values `fib[2] .. fib[19]` are undefined.

In the last case, C infers the array length (as if we declared `vec[5]`).

21

Arrays and Functions

- When an array is passed as a parameter to a function, the address of the start of the array is actually passed
- Example:

```
int total, vec[20];  
...  
total = sum(vec);
```

Within the function, the types of elements in the array are known, and the size of the array is unknown

22

Multi-dimensional Arrays

- Examples:

```
float q[2][2];
```

$$\begin{bmatrix} 0.5 & 2.7 \\ 3.1 & 0.1 \end{bmatrix}$$

```
int r[3][4];
```

$$\begin{bmatrix} 5 & 10 & -2 & 4 \\ 0 & 2 & 4 & 8 \\ 21 & 2 & 1 & 42 \end{bmatrix}$$

Note: $q[0][1]==2.7$, $r[1][3]==8$, $q[1]==\{3.1,0.1\}$.

- Multi-dimensional arrays can also be initialised:

```
float q[][] = {{0.5, 2.7}, {3.1, 0.1}};
```

23

Giving Data Types New Names

- C allows us to give a new name to a data type via typedef:

```
typedef ExistingDataType NewTypeName;
```

- Examples:

```
typedef char BYTE;  
BYTE x1, x2;
```

- By convention, uppercase letters are used to remind the user that the type name is really a symbolic abbreviation, but you can use lowercase:

```
typedef char byte;  
byte x1, x2;
```

24

Structures

- A structure is a collection of variables, perhaps of different types, grouped together under a single name
- It helps to organise complicated data into manageable entities
- It exposes the connection between data within an entity
- It is defined using the `struct` keyword
- Example:

```
struct date {  
    int day;  
    int month;  
    int year;  
}; // don't forget the semicolon!
```

25

typedef and struct

- We can also define a structured data type TicketT for speeding ticket objects:

```
typedef struct {  
    int day, month, year;  
} DateT;  
  
typedef struct {  
    int hour, minute;  
} TimeT;  
  
typedef struct {  
    char plate[7]; // e.g. "DSA42X"  
    double speed;  
    DateT d;  
    TimeT t;  
} TicketT;
```

26

Basic I/O in C

- C programming treats all the I/O devices as files. So I/O devices such as the display are handled in the same way as files.
- The following three files are automatically opened when a program executes to provide access to the keyboard and screen:
 - Standard input `stdin` for keyboard
 - Standard output `stdout` for screen
 - Standard error `stderr` for screen

27

`getchar()` and `putchar()`

`int getchar(void)`

- Reads the next available character from keyboard and returns it as an integer

`int putchar(int c)`

- Puts the passed character on the screen and returns the same character

```
#include <stdio.h>
int main() {

    int c;

    printf( "Enter a value :");
    c = getchar( );

    printf( "\n You just entered: ");
    putchar( c );

    return 0;
}
```

28

gets() and puts()

`char *gets(char *s)`

- Reads a line from stdin into the buffer pointed to by s until either a terminating newline or EOF (End of File)

`int puts(const char *s)`

- Writes the string s and a trailing newline to stdout

```
#include <stdio.h>
int main( ) {
    char str[30];
    printf( "Please enter a value :");
    gets( str );
    printf( "\nYou just entered: ");
    puts( str );
    return 0;
}
```

29

scanf() and printf()

`int scanf(const char *format, ...)`

- Reads the input from the standard input stream `stdin` and scans it according to the format provided

`int printf(const char *format, ...)`

- Writes the output to the standard output stream `stdout` and produces the output according to the format provided

```
#include <stdio.h>
int main( ) {
    char str[30];
    int i;
    printf( "Please enter a value :");
    scanf("%s %d", str, &i);
    printf( "\nYou just entered: %s %d ", str, i);
    return 0;
}
```

30

fopen()

`fopen()` creates a new file or to open an existing file.

```
FILE *fopen( const char * filename, const char * mode );
```

where the access mode can have one of the following values:

r: Opens an existing text file for reading.

w: Opens a text file for writing. If it does not exist, then a new file is created.

a: Opens a text file for writing in appending mode. If it does not exist, then a new file is created.

r+: Opens a text file for both reading and writing.

w+: Opens a text file for both reading and writing. It first truncates the file to zero length if it exists, otherwise creates a file if it does not exist.

a+: Opens a text file for both reading and writing. It creates the file if it does not exist. The reading will start from the beginning but writing can only be appended.

fclose()

```
int fclose( FILE *fp );
```

- `fclose()` returns zero on success, or EOF if there is an error in closing the file. It flushes any data still pending in the buffer to the file, closes the file, and releases any memory used for the file. The EOF is a constant defined in the header file `stdio.h`.

fgetc() and fgets()

`int fgetc(FILE *pointer);`

It returns the character at the position indicated by file pointer. After reading the character, the file pointer is advanced to next character. If the pointer is at the end of file or if an error occurs, EOF is returned.

`char *fgets(char *buf, int n, FILE *fp);`

It reads up to n-1 characters from the input stream referenced by fp and copies the read string into the buffer buf, appending a null character to terminate the string.

33

fputc() and fputs()

`int fputc(int c, FILE *fp);`

It writes the given character at the position denoted by the file pointer and then advances the file pointer. This function returns the character written in case of successful write operation, or EOF is returned in case of error.

`int fputs(const char *s, FILE *fp);`

It writes the string s to the output stream referenced by fp. It returns a non-negative value on success; otherwise EOF is returned in case of any error.

34

Examples

```
#include <stdio.h>

main() {
    FILE *fp;

    fp = fopen("test.txt", "w+");
    fputs("This is testing for fputs\n", fp);
    fclose(fp);
}

#include <stdio.h>

main() {
    FILE *fp;
    char buff[50];

    fp = fopen("test.txt", "r");
    fgets(buff, 50, (FILE*)fp);
    printf("%s\n", buff );
    fclose(fp);
}
```

35

fread()

```
size_t fread(void *ptr, size_t size, size_t nmemb, FILE *stream);
```

It reads data from the given stream into the array pointed to, by ptr.

Parameters

- ptr – The pointer to a block of memory with a minimum size of size*nmemb bytes.
- size – The size in bytes of each element to be read.
- nmemb – The number of elements, each one with a size of size bytes.
- stream – The pointer to a FILE object that specifies an input stream.

Return Value

- The total number of elements successfully read is returned as a size_t object, which is an integral data type. If this number differs from the nmemb parameter, then either an error has occurred or the End Of File was reached.

36

fwrite()

`size_t fwrite(const void *ptr, size_t size, size_t nmemb, FILE *stream);`

It writes data from the array pointed to, by ptr to the given stream.

Parameters

- ptr – This is the pointer to the array of elements to be written.
- size – This is the size in bytes of each element to be written.
- nmemb – This is the number of elements, each one with a size of size bytes.
- stream – This is the pointer to a FILE object that specifies an output stream.

Return Value

- On success, it returns the count of the number of elements successfully written to the file. On error, it returns a number less than n.

37

Example 1

```
#include<stdio.h>
struct Student
{
    int roll;
    char name[30];
    float marks;
};
int main()
{
    FILE *fp;
    char ch;
    struct Student S;
    fp = fopen("Student.dat", "r");
    if(fp == NULL)
    {
        printf("\nCan't open file or file doesn't exist.");
        exit(0);
    }

    printf("\n\tRoll\tName\tMarks\n");
    while (fread(&S, sizeof(S), 1, fp) > 0)
        printf("\n\t%d\t%s\t%f", S.roll, S.name, S.marks);
    fclose(fp);
    Return 0;
}
```

38

Example 2

```
#include<stdio.h>
#include<stdlib.h>
struct Student
{
    int roll;
    char name[30];
    float marks;
};
int main()
{
    FILE *fp;
    char ch;
    struct Student S;
    fp = fopen("Student.dat", "w");
    if (fp == NULL)
    {
        printf("\nCan't open file or file doesn't exist.");
        exit(0);
    }
    do
    {
        printf("\nEnter Roll : ");
        scanf("%d",&S.roll);
        printf("Enter Name : ");
        scanf("%s",S.name);
        printf("Enter Marks : ");
        scanf("%f",&S.marks);
        fwrite(&S,sizeof(S),1,fp);
        printf("\nDo you want to add another data (y/n) : ");
        ch = getchar();
    } while(ch=='y' || ch=='Y');
    printf("\nData have been written successfully.");
    fclose(fp);
    return 0;
}
```

39

Summary

- Introduction to C programming language, compiling with gcc
 - Basic data types (char, int, float)
 - Basic programming constructs (if ... else conditionals, while loops, for loops)
 - Basic data structures (atomic data types, arrays, structures)
 - Functions
 - Basic I/O
- Suggested reading (Moffat):
 - Introduction to C ... Ch.1; Ch.2.1-2.3, 2.5-2.6;
 - Conditionals and loops ... Ch.3.1-3.3; Ch.4.1-4.4
 - Functions Ch. 5
 - Arrays ... Ch.7.1,7.5-7.6
 - Structures ... Ch.8.1
 - File Operations Ch. 11

40

Useful Links

- GCC compiler <https://gcc.gnu.org/install/download.html>.
- Eclipse C/C++ IDE
<https://www.eclipse.org/downloads/packages/eclipse-ide-cc-developers/lunar>
- https://www.onlinegdb.com/online_c_compiler

This link provides an online editor and compiler for C