

Introduction to C

Stat 580: Statistical Computing

- Theme: [Black - White](#)
- [Printable version](#)

References

- "The C programming language" by Brian W. Kernighan and Dennis M. Ritchie.
- Part of this slide set is based on *Essential C* by Nick Parlante:

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I know R. Why learn C?

- R (high-level, interpreted language) can be *slow*, due to, e.g., its extreme dynamism. (We will cover this later.)
- C (mid-level language) is fast, powerful and widely used. (See [low-level languages](#).)
- C is easy to interface with R.
- C++ (which inherits most of C's syntax) provides easy and powerful interfacing with R, with the help of various R packages (e.g., Rcpp, RcppArmadillo, RcppEigen).

Introduction to C

- C is a general-purpose programming language.
- It is closely associated with UNIX system but not tied to any one operating system or machine.
 - So taking Stat580 is not an excuse to buy a supercomputer.
- B (developed by Ken Thompson in 1969-1970) -> C (developed by Dennis Ritchie during 1971-1973). See [The Development of the C Language](#).

Some elements of C programs

- *variables and constants*
 - basic data types: characters, integers and floating-point numbers
 - complex data types: e.g., pointers, arrays, structures
- *operators (e.g., =, +)*
- *control-flow constructions*
- *functions*

First C program: "hello, world"

"hello, world"

Goal: print the words "hello, world"

This *involves*:

1. write the source code
2. compile it
3. load and run it
4. locate your output

Write the source code

```
#include <stdio.h>

int main()
{
    printf("hello, world\n");
    return 0;
}
```

- (Use any text editor you like! Two classical choices: [Vi \(Vim\)](#) and [Emacs](#).)
- Some general rules:
 - case-sensitive: `Printf` is different from `printf`
 - free-form line structure: you have to end the statement by `;`.
 - statement can span a few lines
 - multiple statements can be on the same line
 - space is ignored

Write the source code

```
#include <stdio.h>

int main()
{
    printf("hello, world\n");
    return 0;
}
```

- `#include <stdio.h>`: loads in `stdio.h` which is called a header file
 - appears at the beginning of the source code
 - to use the standard functions, we usually have to call the corresponding header file
 - `stdio.h` is the header file of C standard input/output library
 - `<file.h>` indicates the header file `file.h` in a standard list of system directories, e.g., `/usr/include`
 - `"file.h"` indicates the header file `file.h` in the current directory

Write the source code

```
#include <stdio.h>

int main()
{
    printf("hello, world\n");
    return 0;
}
```

- C program begins executing at a function `main()`
 - `int` indicates that the `main()` function returns an integer, which matches with the `return` statement.
 - code within `{` and `}` are the code that we want to execute.
 - `main()` usually calls other functions (some that you wrote and others from libraries) to help perform its job .
 - In this case, it calls `printf()` from the standard input/output library.

Write the source code

```
#include <stdio.h>

int main()
{
    printf("hello, world\n");
    return 0;
}
```

- One method of communicating data between functions is to provide a list of values, called arguments, to the function it calls.
 - `printf()` is a function, we supply the argument "hello, world\n"

Compile it

Save the text as "hello.c" and run the following. (We will use gcc compiler, which has already been installed on the [department linux servers](#).)

Basic way

```
gcc hello.c
```

- This will generate an executable file `a.out`.

With name

```
gcc hello.c -o hello.out
```

- This will generate an executable file `hello.out`.

Compile it

-Wall flag: generate warning messages

```
gcc -Wall hello.c
```

Example

```
#include <stdio.h>

int main()
{
    printf("hello, world\n");
    int i=1;
    return 0;
}
```

-ansi and -pedantic flags: for adhering to the **ANSI standard**

```
gcc -ansi -pedantic hello.c
```

Compilation

- Preprocessor
 - scans through the source files, removes comments
 - interprets special preprocessor directives (#)
- Compiler
 - processes the source code to make assembly code, a low-level CPU-specific language
- Assembler
 - makes an object file of machine-ready instructions
- Linker
 - links libraries or multiple source files involved (if any) together to produce the executable

Remaining

Load and run it

On UNIX machines:

```
./a.out
```

Locate your output

```
hello, world
```

Comments

- Comments in C are enclosed by slash/star pairs: `/* .. comments .. */` which may cross multiple lines.
- C++ introduced a form of comment started by two slashes and extending to the end of the line: `// comment until the line end`
- The `//` comment form is so handy that many C compilers now also support it, although it is not technically part of the C language.

```
printf("I am comment\n") // I am comment
/* I am
   comment */
```

- Comments are an important part of well written code:
 - describes what the code accomplishes
 - narrates what is tricky or non-obvious about a section of code

printf () function

- useful function for understanding and debugging C programs
- general form: `printf(<string>, list of arguments)`
 - `printf("hello world\n")` has a string "hello world\n" and no arguments
- In general, <string> consists of three elements:
 - text to be displayed
 - format specifiers (to be replaced by the arguments in the display)
 - special characters
- "hello world\n" contains no format specifier, but
 - text to be displayed: `hello world`
 - special characters: `\n` (newline). [See other special characters.](#)

Example

```
#include <stdio.h>

int main()
{
    printf("hello, ");
    printf("world");
    printf("\n");
    return 0;
}
```

Second C program: temperature conversion

Temperature conversion

Goal: print a correspondence table of Fahrenheit temperatures and their Celsius equivalents using

$$C = (5/9)(F - 32)$$

```
#include <stdio.h>

int main() {
    int f, c, lower, upper, step;

    lower = 0;      /* lower limit of the table */
    upper = 200;    /* upper limit */
    step = 25;      /* step size */

    f = lower;
    printf("F\tC\n"); /* table header */
    while (f <= upper) {
        c = 5 * (f - 32) / 9; /* integer arithmetic */
        printf("%d\t%d\n", f, c);
        f = f + step;
    }
    return 0;
}
```

Variables

- Different from R, variables must be declared before use.
- A simple declaration statement looks like this:

```
int x;
```

- It consists of variable type `int` and variable name `x`.
- `int` indicates that `x` is an integer.
- Other types will be introduced later.

In the example,

```
int f, c, lower, upper, step;
```

- Several variables are declared in one statement.
 - `f, c, lower, upper` and `step` are all declared to be of type `int`.

Understanding the program

```
#include <stdio.h>

int main() {
    int f, c, lower, upper, step;

    lower = 0;    /* lower limit of the table */
    upper = 200;  /* upper limit */
    step = 25;    /* step size */

    f = lower;
    printf("F\tC\n"); /* table header */
    while (f <= upper) {
        c = 5 * (f - 32) / 9; /* integer arithmetic */
        printf("%d\t%d\n", f, c);
        f = f + step;
    }
    return 0;
}
```

printf () - a closer look

- general form: `printf(<string>, list of arguments)` where `<string>` consists of three elements:
 - text to be displayed
 - format specifiers (to be replaced by the arguments in the display)
 - special characters

printf () - a closer look

```
printf("%d\t%d\n", f, c);
```

- %d is a format specifier
 - %d specifies a decimal integer (as opposed to e.g. binary integer).
 - In the display, format specifiers are replaced by the arguments in the same order.
 - The first %d is replaced by the value of f.
 - The second %d is replaced by the value of c.

Format specifiers

Format specifier	Description
%d	decimal integer
%5d	decimal integer, at least 5 characters wide
%f	floating pointer number
%5f	floating pointer number, at least 5 characters wide
%.2f	floating pointer number, 2 characters after decimal point
%5.2f	floating pointer number, at least 5 character wide and 2 characters after decimal point

See [format specifiers](#).

while loop

while loop is one of the control structures, which control the flow of the program.

```
while (<expression>) {  
    <statement>  
}
```

- While the <expression> is true, the loop continues.
- <expression> is evaluated before every loop.

```
while (f <= upper) {  
    c = 5 * (f - 32) / 9;    /* integer arithmetic */  
    printf("%d\t%d\n", f, c);  
    f = f + step;  
}
```

Integer arithmetic

- output from the temperature conversion program:

F	C
0	-17
25	-3
50	10
75	23
100	37
125	51
150	65
175	79
200	93

- e.g., $5(0 - 32)/9 = -17.77778$ and $5(200 - 32)/9 = 93.33333$.
- The conversion takes away the decimal digits.
- The reason is that the variables in $5 * (f - 32) / 9$ are all of integer type
 - which leads to integer arithmetic: the decimal digits are removed
- What is the result of $3/5$?

Using floating point type

```
#include <stdio.h>

int main() {
    double f, c;
    int lower, upper, step;

    lower = 0;    /* lower limit of the table */
    upper = 200;  /* upper limit */
    step = 25;    /* step size */

    f = lower;
    printf("F\tC\n");    /* table header */
    while (f <= upper) {
        c = 5.0 * (f - 32.0) / 9.0;
        printf("%.0f\t%.1f\n", f, c); /* rounding */
        f = f + step;
    }
    return 0;
}
```

Symbolic constants

- `lower`, `upper` and `step` are tuning parameters.
- We want to provide a systematic way for one to change them without digging into the program.
- We can use `#define` preprocessor directive.

```
#define lower 0  
#define upper 200  
#define step 25
```

- The preprocessor will replace the symbols (`lower`, `upper`, `step`) by their values (0, 200, 25) before compilation.

Symbolic constants

This program

```
#include <stdio.h>
#define lower 0
#define upper 200
#define step 25

int main() {
    double f, c;

    f = lower;
    printf("F\tC\n");    /* table header */
    while (f <= upper) {
        c = 5.0 * (f - 32.0) / 9.0;
        printf("%.0f\t%.1f\n", f, c); /* rounding */
        f = f + step;
    }
    return 0;
}
```

Symbolic constants

is equivalent to this one:

```
#include <stdio.h>

int main() {
    double f, c;

    f = 0;
    printf("F\tC\n");    /* table header */
    while (f <= 200) {
        c = 5.0 * (f - 32.0) / 9.0;
        printf("%.0f\t%.1f\n", f, c); /* rounding */
        f = f + 25;
    }
    return 0;
}
```

Character input and output

Standard I/O library

- In standard library, the input or output is dealt with as streams of characters.
- A text stream is a sequence of characters divided into lines.
- Each line consists of zero or more characters followed by a newline character.
- We will focus on:
 - `getchar ()`: reads the next input character
 - `putchar (c)`: prints the character stored in `c`

File copying

```
#include<stdio.h>

int main(){
    int c;

    c = getchar();
    while (c != EOF){
        putchar(c);
        c = getchar();
    }
    return 0;
}
```

- Variable `c` is declared to be an `int`.
 - We usually declare a character as `char`.
 - However, `getchar()` distinguishes the end of the input from valid data by returning `EOF` (end of line) if it hits the end.
 - `EOF` does not belong to `char` and thus we need a bigger type which is `int` (this will be made clear in the next slide set).

Character counting

```
#include <stdio.h>

/* count characters in input */
int main() {
    int count;

    count = 0;
    while (getchar() != EOF) {
        count = count + 1; /* count++ */
    }
    printf("\nNumber of characters: %d.\n", count);
    return 0;
}
```

Guess how many words if we type in the following without hitting "Enter" in the last line.

```
123
```

```
45
```

How can you count the number of lines?