

CME 211: Lecture 18

Topics:

- Functions
- Preprocessor & `#include` statements

Functions

- Functions allow us to decompose a program into smaller components
- It is easier to implement, test, and debug portions of a program in isolation
- Allows work to be spread among many people working mostly independently
- If done properly it can make your program easier to understand and maintain
- Eliminate duplicated code
- Reuse functions across multiple programs

C/C++ function

Example:

```
int sum(int a, int b) {  
    int c = a + b;  
    return c;  
}
```

Components:

```
return_type function_name(argument_type1 argument_var1, ...) {  
    // function body  
    return return_var; // return_var must have return_type  
}
```

sum function in use

src/sum1.cpp

```
#include <iostream>
```

```
int sum(int a, int b) {  
    int c = a + b;  
    return c;  
}
```

```
int main() {  
    int a = 2, b = 3;  
  
    int c = sum(a,b);  
    std::cout << "c = " << c << std::endl;  
  
    return 0;  
}
```

Output:

```
$ g++ -Wall -Wextra -Wconversion sum1.cpp -o sum1
$ ./sum1
c = 5
```

Order matters

src/sum2.cpp:

```
#include <iostream>

int main() {
    int a = 2, b = 3;

    // the compiler does not yet know about sum()
    int c = sum(a,b);
    std::cout << "c = " << c << std::endl;

    return 0;
}

int sum(int a, int b) {
    int c = a + b;
    return c;
}
```

Output:

```
$ g++ -Wall -Wextra -Wconversion sum2.cpp -o sum2
sum2.cpp: In function 'int main()':
sum2.cpp:7:18: error: 'sum' was not declared in this scope
    int c = sum(a,b);
               ^
```

Function declarations and definitions

- A function *definition* is the code that implements the function
- It is legal to call a function if it has been defined or *declared* previously
- A function *declaration* specifies the function name, input argument type(s), and output type. The function *declaration* need not specify the implementation (code) for the function.

src/sum3.cpp:

```
#include <iostream>

// Forward declaration or prototype
int sum(int a, int b);

int main() {
    int a = 2, b = 3;

    int c = sum(a,b);
    std::cout << "c = " << c << std::endl;
```

```

    return 0;
}

// Function definition
int sum(int a, int b) {
    int c = a + b;
    return c;
}

```

Output:

```

$ g++ -Wall -Wextra -Wconversion sum3.cpp -o sum3
$ ./sum3
c = 5

```

Data types

```

src/datatypes1.cpp
#include <iostream>

int sum(int a, int b) {
    int c;
    c = a + b;
    return c;
}

int main() {
    double a = 2.7, b = 3.8;

    int c = sum(a,b);
    std::cout << "c = " << c << std::endl;

    return 0;
}

```

Output:

```

$ g++ -Wall -Wextra -Wconversion datatypes1.cpp -o datatypes1
datatypes1.cpp: In function 'int main()':
datatypes1.cpp:14:18: warning: conversion to 'int' from 'double' may alter its value [-Wconversion]
    int c = sum(a,b);
                  ^
datatypes1.cpp:14:18: warning: conversion to 'int' from 'double' may alter its value [-Wconversion]
$ ./datatypes1
c = 5

```

Implicit casting

```

src/datatypes2.cpp:
#include <iostream>

int sum(int a, int b) {
    double c = a + b;
    return c; // we are not returning the correct type
}

```

```

}

int main() {
    double a = 2.7, b = 3.8;

    int c = sum(a,b);
    std::cout << "c = " << c << std::endl;

    return 0;
}

```

Output:

```

$ g++ -Wall -Wextra -Wconversion datatypes2.cpp -o datatypes2
datatypes2.cpp: In function 'int sum(int, int)':
datatypes2.cpp:6:10: warning: conversion to 'int' from 'double' may alter its value [-Wconversion]
    return c;
           ^
datatypes2.cpp: In function 'int main()':
datatypes2.cpp:13:18: warning: conversion to 'int' from 'double' may alter its value [-Wconversion]
    int c = sum(a,b);
                   ^
datatypes2.cpp:13:18: warning: conversion to 'int' from 'double' may alter its value [-Wconversion]
$ ./datatypes2
c = 5

```

Explicit casting

```

src/datatypes3.cpp

#include <iostream>

int sum(int a, int b) {
    double c = a + b;
    return (int)c;
}

int main() {
    double a = 2.7, b = 3.8;

    int c = sum((int)a,(int)b);
    std::cout << "c = " << c << std::endl;

    return 0;
}

```

Output:

```

$ g++ -Wall -Wextra -Wconversion datatypes3.cpp -o datatypes3

```

void

- Use the void keyword to indicate absence of data
- src/void1.cpp

```

#include <iostream>

void printHeader(void) {
    std::cout << "-----" << std::endl;
    std::cout << "    MySolver v1.0    " << std::endl;
    std::cout << "-----" << std::endl;
}

int main() {
    printHeader();
    return 0;
}

```

Output:

```

$ g++ -Wall -Wextra -Wconversion void1.cpp -o void1
$ ./void1

```

```

-----
    MySolver v1.0
-----

```

void and return

src/void2.cpp:

```

#include <iostream>

void printHeader(void) {
    std::cout << "-----" << std::endl;
    std::cout << "    MySolver v1.0    " << std::endl;
    std::cout << "-----" << std::endl;
    return 0;
}

int main() {
    printHeader();
    return 0;
}

```

Output:

```

$ g++ -Wall -Wextra -Wconversion void2.cpp -o void2
void2.cpp: In function 'void printHeader()':
void2.cpp:8:10: error: return-statement with a value, in function returning 'void' [-fpermissive]
    return 0;
    ^

```

void and return

src/void3.cpp:

```

#include <iostream>

void printHeader(void) {
    std::cout << "-----" << std::endl;
    std::cout << "    MySolver v1.0    " << std::endl;
}

```

```

    std::cout << "-----" << std::endl;
    return;
}

int main() {
    printHeader();
    return 0;
}

```

Output:

```
$ g++ -Wall -Wextra -Wconversion void3.cpp -o void3
```

Ignoring return value

src/ignore.cpp:

```

#include <iostream>

int sum(int a, int b) {
    int c = a + b;
    return c;
}

int main() {
    int a = 2, b = 3;

    sum(a,b); // legal to ignore return value if you want

    return 0;
}

```

Output:

```
$ g++ -Wall -Wextra -Wconversion ignore.cpp -o ignore
$ ./ignore
```

Function scope

src/scope1.cpp:

```

#include <iostream>

int sum(void) {
    // a and b are not in the function scope
    int c = a + b;
    return c;
}

int main() {
    int a = 2, b = 3;

    int c = sum();
    std::cout << "c = " << c << std::endl;
}

```

```
    return 0;
}
```

Output:

```
$ g++ -Wall -Wextra -Wconversion scope1.cpp -o scope1
scope1.cpp: In function 'int sum()':
scope1.cpp:5:11: error: 'a' was not declared in this scope
    int c = a + b;
            ^
scope1.cpp:5:15: error: 'b' was not declared in this scope
    int c = a + b;
              ^
...
```

Global scope

src/scope2.cpp:

```
#include <iostream>

// an be accessed from anywhere in the file (bad, bad, bad)
int a;

void increment(void) {
    a++;
}

int main() {
    a = 2;

    std::cout << "a = " << a << std::endl;
    increment();
    std::cout << "a = " << a << std::endl;

    return 0;
}
```

Output:

```
$ g++ -Wall -Wextra -Wconversion scope2.cpp -o scope2
$ ./scope2
a = 2
a = 3
```

Passing arguments

src/passing1.cpp:

```
#include <iostream>

void increment(int a) {
    a++;
    std::cout << "a = " << a << std::endl;
}
```

```

int main() {
    int a = 2;

    increment(a);
    std::cout << "a = " << a << std::endl;

    return 0;
}

```

Output:

```

$ g++ -Wall -Wextra -Wconversion passing1.cpp -o passing1
$ ./passing1
a = 3
a = 2

```

Passing arguments

src/passing2.cpp:

```

#include <iostream>

void increment(int a[2]) {
    a[0]++;
    a[1]++;
}

int main() {
    int a[2] = {2, 3};

    std::cout << "a[0] = " << ", " << "a[1] = " << std::endl;
    increment(a);
    std::cout << "a[0] = " << ", " << "a[1] = " << std::endl;

    return 0;
}

```

Output:

```

$ g++ -Wall -Wextra -Wconversion passing2.cpp -o passing2
$ ./passing2
a[0] = 2, a[1] = 3
a[0] = 3, a[1] = 4
a[0] = 3, a[1] = 4

```

Pass by value

- C/C++ default to pass by value, which means that when calling a function the arguments are copied
- However, you need to be careful and recognize what is being copied
- In the case of a number like `int a`, what is being copied is the value of the number
- For a static array like `int a[2]`, what is being passed and copied is the location in memory where the array data is stored
- Will discuss pass by reference when we get to data structures

Towards modularity

src/main4.cpp:

```
#include <iostream>

int sum(int a, int b);

int main() {
    int a = 2, b = 3;

    int c = sum(a,b);
    std::cout << "c = " << c << std::endl;

    return 0;
}
```

src/sum4.cpp:

```
int sum(int a, int b) {
    int c = a + b;
    return c;
}
```

Output:

```
$ g++ -Wall -Wextra -Wconversion main4.cpp sum4.cpp -o sum4
$ ./sum4
c = 5
```

Maintaining consistency

src/main5.cpp:

```
#include <iostream>

int sum(int a, int b);

int main() {
    int a = 2, b = 3;

    int c = sum(a,b);
    std::cout << "c = " << c << std::endl;

    return 0;
}
```

src/sum5.cpp:

```
double sum(double a, double b) {
    double c = a + b;
    return c;
}
```

Output:

```
$ g++ -Wall -Wextra -Wconversion main5.cpp sum5.cpp -o sum5
/tmp/ccCKlsvX.o: In function main':
```

```
main5.cpp:(.text+0x21): undefined reference to sum(int, int)'  
collect2: error: ld returned 1 exit status
```

The preprocessor and #include

- We have used functionality from the C++ standard library for output to the screen using `cout`, performing I/O with files, using the string object, etc.
- A library is a collection of functions, data types, constants, class definitions, etc.
- Somewhat analogous to a Python module
- At a minimum, accessing the functionality of a library requires `#include` statements

#include

- So what actually happens when you put something like `#include <iostream>` in your file?
- `<iostream>` is a way of referring to a file called `iostream` that is part of the compiler installation and on the corn machines is found at `/usr/include/c++/4.8/iostream`
- These types of files are called include or header files and contains forward declarations (prototypes) of functions, class definitions, constants, etc.

Preprocessor

- Before files are processed by the compiler, they are run through the C preprocessor, `cpp`
- What does the preprocessor do?
- For one thing it processes those `#include` statements

Hacking the preprocessor

```
$ cpp -P goodbye.txt  
Hello!
```

Goodbye!

```
$ cat hello.txt  
Hello!  
$ cat goodbye.txt  
#include "hello.txt"  
Goodbye!
```

```
$ cpp -P goodbye.txt  
Hello!
```

Goodbye!

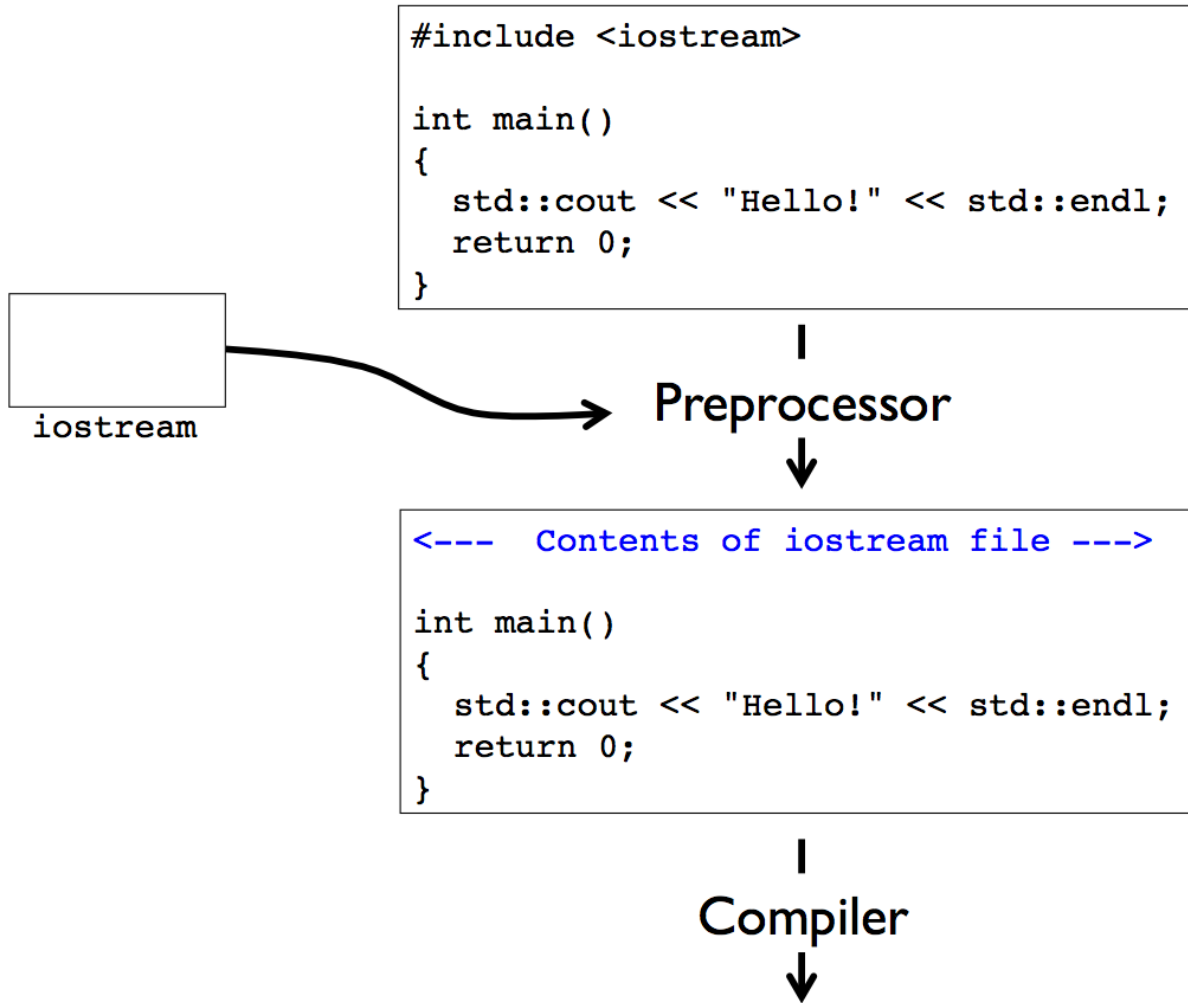


Figure 1: fig

Compilation process

Standard decomposition

- Function (and type) *declarations* go in header (.hpp) files
- Function *definitions* go in source (.cpp) files
- Source files that want to use the functions must **#include** the header

src/main6.cpp:

src/sum6.hpp

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

src/sum6.cpp:

```
#include "sum6.hpp"
```

```
double sum(double a, double b) {  
    double c = a + b;  
    return c;  
}
```

Output:

```
$ g++ -Wall -Wextra -Wconversion main6.cpp sum6.cpp -o sum6
```

```
$ ./sum6
```

```
c = 5
```

#include syntax

- The .hpp file extension denotes a C++ header file
- < > around the file name means that the preprocessor should search for an include file in a system dependent or default directory
- These are typically include files that come with the compiler like `iostream`, `fstream`, `string`, etc.
- Usually these files are somewhere in `/usr/include` with the GNU compilers on Linux
- "header.hpp" means that the preprocessor should first search in the user directory, followed by a search in a system dependent or default directory if necessary

#define

src/define1.cpp:

```
// define ni and nj to be 16
```

```
#define ni 16
```

```
#define nj 16
```

```
int main() {  
    int a[ni][nj];  
  
    for(int i = 0; i < ni; i++) {
```

```

    for(int j = 0; j < nj; j++) {
        a[i][j] = 1;
    }
}

return 0;
}

```

Pass the code through the preprocessor:

```
$ cpp -P define1.cpp
```

```
// define ni and nj to be 16
```

```

int main() {
    int a[16][16];

    for(int i = 0; i < 16; i++) {
        for(int j = 0; j < 16; j++) {
            a[i][j] = 1;
        }
    }

    return 0;
}

```

Macros

- Real power of `#define` is in setting up macros
- Similar to functions but handled by the preprocessor

`#define macro`

```
src/define2.cpp
```

```
#include <iostream>
```

```
#define sqr(n) (n)*(n)
```

```

int main() {
    int a = 2;

    int b = sqr(a);
    std::cout << "b = " << b << std::endl;

    return 0;
}

```

Output:

```

$ g++ -Wall -Wextra -Wconversion define2.cpp -o define2
$ ./define2
b = 4

```

Be careful

src/define3.cpp:

```
#include <iostream>

#define sqr(n) n*n

int main() {
    int a = 2;

    int b = sqr(a+3);
    std::cout << "b = " << b << std::endl;

    return 0;
}
```

Output:

```
$ g++ -Wall -Wextra -Wconversion define3.cpp -o define3
$ ./define3
b = 11
```

Predefined macros

src/define4.cpp:

```
#include <iostream>

int main() {
    std::cout << "This line is in file " << __FILE__
              << ", line " << __LINE__ << std::endl;
    return 0;
}
```

Output:

```
$ g++ -Wall -Wextra -Wconversion define4.cpp -o define4
$ ./define4
This line is in file define4.cpp, line 5
```

Conditional compilation

src/conditional.cpp:

```
#include <iostream>

#define na 4

int main() {
    int a[na];

    a[0] = 2;
    for (int n = 1; n < na; n++) a[n] = a[n-1] + 1;

#ifdef DEBUG
```

```

    // Only kept by preprocessor if DEBUG defined
    for (int n = 0; n < na; n++) {
        std::cout << "a[" << n << "] = " << a[n] << std::endl;
    }
#endif

    return 0;
}

```

Output:

```

$ g++ -Wall -Wextra -Wconversion conditional.cpp -o conditional
$ ./conditional
$ g++ -Wall -Wextra -Wconversion conditional.cpp -o conditional -DDEBUG
$ ./conditional
a[0] = 2
a[1] = 3
a[2] = 4
a[3] = 5

```

Reading

- **C++ Primer, Fifth Edition** by Lippman et al.
- Chapter 6: Functions: Sections 6.1 - 6.3