C++ Programming

Week 5:

Functions

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Week 5: Agenda

- Review Arrays, Strings, Vectors
- Review Homework 4)
- New Topic: Functions

Two types of strings in C++

- In C++, we have two types of strings:

1) std::string

- The std::string class that's provided by the C++ Standard Library is the preferred method to use for strings.

2) C-style Strings

- These are strings derived from the C programming language and they continue to be supported in C++.
- These "collections of characters" are stored in the form of arrays of type char that are null-terminated (the \0 null character).
- C-style strings are relatively unsafe and not recommended.

Defining and Initializing **`string`s**

Each class defines how objects of its type can be initialized. A class may define many different ways to initialize objects of its type. Each way must be distin- guished from the others either by the number of initializers that we supply, or by the types of those initializers. Table 3.1 lists the most common ways to initialize `string`s. Some examples:

Table 3.1: Ways to Initialize a `string`

`string s1`	Default initialization; `s1` is the empty string.
`string s2(s1)`	`s2` is a copy of `s1`.
`string s2 = s1`	Equivalent to `s2(s1)`, `s2` is a copy of `s1`.
`string s3("value")`	`s3` is a copy of the string literal, not including the null.
`string s3 = "value"`	Equivalent to `s3("value")`, `s3` is a copy of the string literal.
`string s4(n, 'c')`	Initialize `s4` with `n` copies of the character `'c'`.

`string` Operations

Table 3.2: `string` Operations	
`os << s`	Writes `s` onto output stream `os`. Returns `os`.
`is >> s`	Reads whitespace-separated string from `is` into `s`. Returns `is`.
`getline(is, s)`	Reads a line of input from `is` into `s`. Returns `is`.
`s.empty()`	Returns `true` if `s` is empty; otherwise returns `false`.
`s.size()`	Returns the number of characters in `s`.
`s[n]`	Returns a reference to the `char` at position `n` in `s`; positions start at 0.
`s1 + s2`	Returns a `string` that is the concatenation of `s1` and `s2`.
`s1 = s2`	Replaces characters in `s1` with a copy of `s2`.
`s1 == s2`	The `strings` `s1` and `s2` are equal if they contain the same characters.
`s1 != s2`	Equality is case-sensitive.
`<, <=, >, >=`	Comparisons are case-sensitive and use dictionary ordering.

`string` cctype functions

Table 3.3: `cctype` Functions

`isalnum(c)`	`true` if `c` is a letter or a digit.
`isalpha(c)`	`true` if `c` is a letter.
`iscntrl(c)`	`true` if `c` is a control character.
`isdigit(c)`	`true` if `c` is a digit.
`isgraph(c)`	`true` if `c` is not a space but is printable.
`islower(c)`	`true` if `c` is a lowercase letter.
`isprint(c)`	`true` if `c` is a printable character (i.e., a space or a character that has a visible representation).
`ispunct(c)`	`true` if `c` is a punctuation character (i.e., a character that is not a control character, a digit, a letter, or a printable whitespace).
`isspace(c)`	`true` if `c` is whitespace (i.e., a space, tab, vertical tab, return, newline, or formfeed).
`isupper(c)`	`true` if `c` is an uppercase letter.
`isxdigit(c)`	`true` if `c` is a hexadecimal digit.
`tolower(c)`	If `c` is an uppercase letter, returns its lowercase equivalent; otherwise returns `c` unchanged.
`toupper(c)`	If `c` is a lowercase letter, returns its uppercase equivalent; otherwise returns `c` unchanged.

Arrays - C-style arrays

- Syntax:
- Type *array name*[size] {…};

```
#include <iostream>
using namespace std;
int main()
{
    int num_array1[5]; // int array
    int num_array2[5] = {0, 1, 2, 3, 4}; // int array
    float f_array1[5]{0.0, 1.0, 2.0, 3.0, 4.0}; // float array
    string s_array1[5]{“w1”, “w2”, “w3”,”w4”, “w5”}; // string array
}
```

Arrays - C++ STL arrays since C++11

- Syntax:
- #include <array>
- Array<T, size> *array_name* {…};

```
#include <iostream>
#include <array>
#include <string>
using namespace std;
int main()
{
   array<int, 5> num_array1{9}; //initialized int array
   array<int, 5> num_array2{0, 1, 2, 3, 4}; //initialized int array
   array<float, 5> float_array3{0.0, 1.0, 2.0, 3.0, 4.0}; //float array
   array<string, 5> s_array5{“”, “”, “”, “”, “”, “”); //string array

}
```

Vector

- A **`vector`** is a collection of objects, all of which have the same type. Everyobject in the collection has an associated index, which gives access to that object. A `vector` is often referred to as a **container** because it "contains" other objects.

- To use a `vector`, we must include the appropriate header. In our examples, we also assume that an appropriate `using` declaration is made:

```
#include <vector>
using std::vector;
```

- A `vector` is a **class template**. C++ has both class and function templates.

Vector Initialization

Table 3.4: Ways to Initialize a `vector`

`vector<T> v1`	`vector` that holds objects of type `T`. Default initialization; `v1` is empty.
`vector<T> v2(v1)`	`v2` has a copy of each element in `v1`.
`vector<T> v2 = v1`	Equivalent to `v2(v1)`, `v2` is a copy of the elements in `v1`.
`vector<T> v3(n, val)`	`v3` has `n` elements with value `val`.
`vector<T> v4(n)`	`v4` has `n` copies of a value-initialized object.
`vector<T> v5{a,b,c...}`	`v5` has as many elements as there are initializers; elements are initialized by corresponding initializers.
`vector<T> v5 = {a,b,c...}`	Equivalent to `v5{a,b,c...}`.

Vector Operations

Table 3.5: `vector` Operations

`v.empty()`	Returns `true` if `v` is empty; otherwise returns `false`.
`v.size()`	Returns the number of elements in `v`.
`v.push_back(t)`	Adds an element with value `t` to end of `v`.
`v[n]`	Returns a reference to the element at position `n` in `v`.
`v1 = v2`	Replaces the elements in `v1` with a copy of the elements in `v2`.
`v1 = {a,b,c ... }`	Replaces the elements in `v1` with a copy of the elements in the comma-separated list.
`v1 == v2` `v1 != v2`	`v1` and `v2` are equal if they have the same number of elements and each element in `v1` is equal to the corresponding element in `v2`.
`<, <=, >, >=`	Have their normal meanings using dictionary ordering.

Range-based `for` Loop

C++11 introduces the **range-based `for` loop** to simplify the verbosity of traditional `for` loop constructs. They are equivalent to the `for` loop operating over a range of values, but **safer**

The range-based `for` loop avoids the user to specify start, end, and increment of the loop

```cpp
for (int v : { 3, 2, 1 }) // INITIALIZER LIST
    cout << v << " ";       // print: 3 2 1

int values[] = { 3, 2, 1 };
for (int v : values)      // ARRAY OF VALUES
    cout << v << " ";     // print: 3 2 1

for (auto c : "abcd")     // RAW STRING
    cout << c << " ";     // print: a b c d
```

Functions

Function Overview

A **function** (**procedure** or **routine**) is a piece of code that performs a *specific task.* Function is a block of code which only runs when it is called.

Purpose:

- **Avoiding code duplication**: less code for the same functionality ⟶ less bugs
- **Readability**: better express what the code does
- **Organization**: break the code in separate modules

Function Overview

- Function is a block of code with a name.
- Declare a function with its name, parameters and return type
- Define a function with details
- Execute a function by calling the function
- A function takes zero or more arguments and usually returns a result.
- Functions can be overloaded, meaning that the same name may have different arguments and different return values

Declaration/Definition

Declaration/Prototype

A **declaration** (or *prototype*) of an entity is an identifier describing its type

A declaration is what the compiler and the linker needs to accept references (usage) to that identifier

C++ entities (class, functions, etc.) can be declared multiple times (with the same signature)

Definition/Implementation

An entity **definition** is the implementation of a declaration

For each entity, only a single *definition* is allowed

Declaration/Definition Function Example

```
void f(int a, string b);  // function declaration  -> put a function declaration in a .h file

void f(int a, string) {   // function definition -> put a function definition in a .cpp file
    ...                   // "b" can be omitted if not used
}

void f(int a, string b);  // function declaration
                          // multiple declarations is valid

f(3, "abc");              // usage
```

```
void g();  // function declaration

g();       // linking error "g" is not defined
```

Examples: Declare a function

```
#ifndef LOCALMATH_H
#define LOCALMATH_H

//definition in LocalMath.cc
int fact(int);        // iterative definition of factorial
#endif
```

Examples: define a function: LocalMath.cpp

```
#include "LocalMath.h"

// factorial of val is val*(val-1)*(val-2) . . . * ((val-(val-1)) * 1)
long fact(int val)
{
    long ret = 1; // local variable to hold the result as we calculate it
    while (val > 1)
        ret *= val--;  // assign ret * val to ret and decrement val
    return ret;        // return the result
}
```

Examples: call a function from main(): fact.cpp

```cpp
#include <iostream>
using namespace std;
#include "LocalMath.h"

int main()
{
    cout << fact(5) << endl;
    cout << fact(0) << endl;

    return 0;
}
```

Recursion

A function that calls itself, either directly or indirectly, is a ***recursive function***.

Examples: Recursive Function

```
#include "LocalMath.h"

// recursive version of factorial:
// calculate val!, which is 1 * 2 * 3 . . . * val
long factorial(int val)
{
    if (val > 1)
        return factorial(val-1) * val;
    return 1;
}
```

Recursion

Trace of `factorial(5)`

Call	Returns	Value
`factorial(5)`	`factorial(4) * 5`	120
`factorial(4)`	`factorial(3) * 4`	24
`factorial(3)`	`factorial(2) * 3`	6
`factorial(2)`	`factorial(1) * 2`	2
`factorial(1)`	1	1

Examples: Compare both factorial functions

```
#include <iostream>
#include <array>
#include <chrono>
using namespace std;
using namespace std::chrono;
#include "LocalMath.h“

int main()
{
    array<int, 9>  n{0, 5, 6, 7, 8, 9, 10, 20, 40};
    //Version 1 - while loop
    auto time_start = high_resolution_clock::now();
    cout << "Factorial function - Version 1: fact() - while loop" << endl;
    for(int i:n) cout << i <<  "! = " << factorial(i) << endl;
    auto run_time = duration_cast<microseconds>(high_resolution_clock::now() - time_start);
    cout << "Elapsed Time = " << run_time.count() << " microseconds (1/million seconds)" << endl;

    //Version 2 - recursive function
    time_start = high_resolution_clock::now();
    cout << "Factorial function - Version 2: factorial() - recursive function" << endl;
    for(int i:n) cout << i <<  "! = " << fact(i) << endl;
    run_time = duration_cast<microseconds>(high_resolution_clock::now() - time_start);
    cout << "Elapsed Time = " << run_time.count() << " microseconds (1/million seconds)" << endl;
    return 0;
}
```

Examples: Compile multiple C++ programs into one executable

```
# Step 1) Compile multiple C++ programs into objects first
$ g++ -c LocalMath.cpp fact.cpp

# Step 2) Link object files into an executable
$ g++ LocalMath.o fact.o -o fact.exe




# Combined one step
$ g++ LocalMath.cpp fact.cpp –o fact.exe
```

Examples: Compare both factorial functions

```
~/cpp/week5$ fact.exe
Factorial function - Version 1: fact() - while loop
0! = 1
5! = 120
6! = 720
7! = 5040
8! = 40320
9! = 362880
10! = 3628800
20! = 2432902008176640000
40! = -70609262346240000
Elapsed Time = 71 microseconds (1/million seconds)
Factorial function - Version 2: factorial() - recursive function
0! = 1
5! = 120
6! = 720
7! = 5040
8! = 40320
9! = 362880
10! = 3628800
20! = 2432902008176640000
40! = -70609262346240000
Elapsed Time = 8 microseconds (1/million seconds)
```

Exercise: Generate Fibonacci numbers using a recursive function

```
// Week 3
int main()
{
    int a = 0, b = 1;
    int temp = 0;
    cout << "First 20 Fibonacci Numbers:" << endl;
    for(int i = 0; i < 20; i++){
        temp = b;
        b = a + b;
        a = temp;
        cout << a << " ";
    }
    cout << endl;

    return 0;
}
```

Exercise: Generate Fibonacci numbers using a recursive function

```cpp
#include <iostream>
#include <vector>
using namespace std;

int fibonacci(int n)
{
    if (n < 3) {
        return 1;
    } else {
        return fibonacci(n-2) + fibonacci(n-1);
    }
}
void fibonacci_sequence(int n, vector<int> & fib_sequence)
{
    if (n == 1) {
        fib_sequence = {1};
    } else if (n == 2) {
        fib_sequence = {1, 1};
    } else {
        for(int i = 2; i <= n; i++){
            fib_sequence.push_back(fibonacci(i));
        }
    }
}
```

```cpp
int main()
{
    vector<int> fib_seq;
    cout << "First 20 Fibonacci Numbers:" << endl;
    fibonacci_sequence(20, fib_seq);
    for (int fib: fib_seq) {
        cout << fib << " ";
    }
    cout << endl;
    return 0;
}
```

Function Parameter and Argument

Function Parameter [formal]

A **parameter** is the variable which is part of the method signature

Function Argument [actual]

An **argument** is the actual value (instance) of the variable that gets passed to the function

```
void f(int a, string b); // parameters: int a, string b
                         // return type: void

f(3, "abc");             // arguments: 3, "abc"
```

Where should a function be? Option 1

```cpp
// draw.cpp
// The function must be defined before it was called
bool drawLine(int x1, int y1, int x2, int y2)
{
   // Source code here
   return true;
}
bool drawRectangle(int x1, int y1, int x2, int y2)
{
   // some calculation here
   drawLine(...);
   drawLine(...);
   drawLine(...);
   drawLine(...);
   return true;
}
```

Where should a function be? Option 2

```cpp
// draw.cpp
// declared first, parameter names can be omitted
bool drawLine(int x1, int y1, int x2, int y2);
bool drawRectangle(int x1, int y1, int x2, int y2)
{
    // some calculation here
    drawLine(...);
    drawLine(...);
    drawLine(...);
    drawLine(...);
    return true;
}
// define it later
bool drawLine(int x1, int y1, int x2, int y2)
{
    // Source code here
    return true;
}
```

Where should a function be? Option 3

```cpp
// draw.h
#ifndef __DRAW_H__
#define __DRAW_H__
bool drawLine(int x1, int y1, int x2, int y2);
bool drawRectangle(int x1, int y1, int x2, int y2);
#endif
```

```cpp
// draw.cpp
#include <draw.h>
bool drawRectangle(int x1, int y1, int x2, int y2)
{
    // some calculation here
    drawLine(...);
    drawLine(...);
    drawLine(...);
    drawLine(...);
    return true;
}
// define it later
bool drawLine(int x1, int y1, int x2, int y2)
{
    // Source code here
    return true;
}
```

```cpp
// main.cpp
#include <draw.h>

int main()
{
    // ...
    drawRectangle(10, 20, 50, 100);
    // ...
}
```

How are functions called?

A call stack can store information about the active functions of a program

Store the address the program returns after the function call
Store the registers
Store the local variables

//do some work of the called function

Restore the registers
Restore the local variables
Store the function returned result
Jump to the return address

The cost to call a function!

Function Parameters

The symbolic name for "data" that passes into a function.

Three ways to pass into a function:

- **Pass by value**
- **Pass by pointer**
- **Pass by reference**

Pass by-Value

Call-by-value

The object is copied and assigned to input arguments of the method `f(T x)`

Advantages:

- Changes made to the parameter inside the function have no effect on the argument

Disadvantages:

- Performance penalty if the copied arguments are large (e.g. a structure with a large array)

When to use:

- Built-in data type and small objects ($\leq$ 8 bytes)

When not to use:

- Fixed size arrays which decay into pointers
- Large objects

Pass by-Pointer

Call-by-pointer

The <u>address</u> of a variable is <u>copied</u> and assigned to input arguments of the method

`f(T* x)`

Advantages:

- Allows a function to change the value of the argument
- Copy of the argument is not made (fast)

Disadvantages:

- The argument may be null pointer
- Dereferencing a pointer is slower than accessing a value directly

When to use:

- *Raw* arrays (use `const T*` if read-only)

When not to use:

- All other cases

Pass by-Reference

Call-by-reference

The reference of a variable is copied and assigned to input arguments of the method

`f(T& x)`

Advantages:

- Allows a function to change the value of the argument (better readability compared with pointers)
- Copy of the argument is not made (fast)
- References must be initialized (no null pointer)
- Avoid implicit conversion (without `const T&`)

When to use:

- All cases except raw pointers

When not to use:

- Pass by-value *could* give performance advantages and improve the readability with built-in data type and small objects

Examples

```cpp
struct MyStruct;

void f1(int a);           // pass by-value
void f2(int& a);          // pass by-reference
void f3(const int& a);    // pass by-const reference
void f4(MyStruct& a);     // pass by-reference

void f5(int* a);          // pass by-pointer
void f6(const int* a);    // pass by-const pointer
void f7(MyStruct* a);     // pass by-pointer

void f8(int*& a);         // pass a pointer by-reference
//------------------------------------------------------------
char c = 'a';
f1(c);      // ok, pass by-value (implicit conversion)
// f2(c); // compile error different types
f3(c);      // ok, pass by-value (implicit conversion)
```

Pass by value: fundamental type

The parameter is a copy of the original variable

```
int foo(int x)
{   // x is a copy
    x += 10;
    return x;
}

int main()
{
    int num1 = 20;
    int num2 = foo( num1 );

    return 0;
}
```

Will `num1` be changed in foo()?

Pass by value: pointer

What's the difference?

```
int foo(int * p)
{
    (*p) += 10;
    return *p;
}

int main()
{
    int num1 = 20;
    int * p = &num1;
    int num2 = foo( p );
    return 0;
}
```

It still is passing by value (the address!)

A copy of the address

param-pointer.cpp

Pass by value: structure

How about structure parameter?

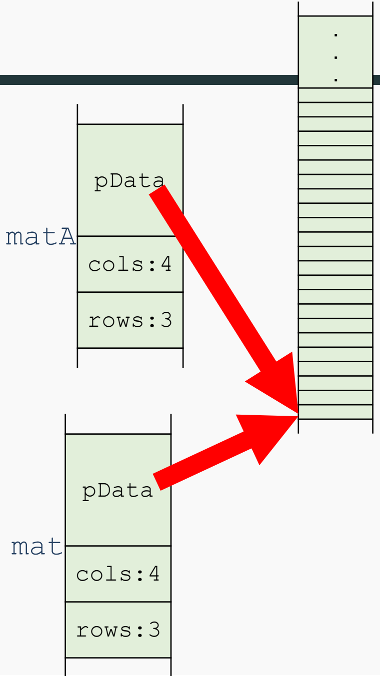
```
struct Matrix
{
    int rows;
    int cols;
    float * pData;
};

float matrix_max(struct Matrix mat)
{
    float max = FLT_MIN;
    for(int r = 0; r < mat.rows; r++)
        for (int c = 0; c < mat.cols; c++)
        {
            float val = mat.pData[ r * mat.cols + c];
            max = ( max > val ? max : val);
        }
    return max;
}
```

Pass by value: structure

```
Matrix matA = {3,4};
matrix_max(matA);
```

```
float matrix_max(struct Matrix mat)
{
   float max = FLT_MIN;
   for(int r = 0; r < mat.rows; r++)
      for (int c = 0; c < mat.cols; c++)
      {
         float val = mat.pData[ r * mat.cols + c];
         max = ( max > val ? max : val);
      }
   return max;
}
```



Pass by value: structure

If the structure is a huge one, such as 1K bytes.
A copy will cost 1KB memory, and time consuming to copy it.

?

References in C++

References are in C++, not in C.
A reference is an alias to an already-existing variable/object.

```
int n = 0;
int &r = n;     //r is a reference to n
r = 10;         // what is the value of n?
int i = 42;
r = i;          //What is the value of n?
```

reference.cpp

References in C++

A reference to an object

```
struct Matrix
{
    int rows;
    int cols;
    float * pData;
};
```

```
Matrix matA = {3,4};
matA.pData = new float[matA.rows * matA.cols]{};

Matrix& matA_ref = matA;

Matrix * pMatA = &matA;
```

References in C++

A reference must be initialized after its declaration.

Reference VS Pointer: References are much safer

```
int& num_ref; // error
Matrix& mat_ref; // error
```

structure

If the huge struct is passed as a function parameter

```
struct PersonInfo
{
    char firstname[256];
    char middlename[256];
    char lastname[256];
    char address[256];
    char nationalID[16];
     // and more
};

char * fullname(struct PersonInfo pi)
{
    // ...
}
```

- The data will be copied. Not a good choice!

The problem

One solution is to use a pointer

```
struct PersonInfo
{
    char firstname[256];
    char middlename[256];
    char lastname[256];
    char address[256];
    char nationalID[16];
     // and more
};
char * fullname(struct PersonInfo * ppi)
{
    if (ppi == NULL)
    {
        cerr << "Invalid pointer" << endl;
        return NULL;
    }
    // ...
}
```

References as function parameters

No data copying in the reference version; Better efficiency

The modification to a reference will affect the original object

```
struct Matrix
{
    int rows;
    int cols;
    float * pData;
};

float matrix_max(struct Matrix mat)
{
    float max = FLT_MIN;
    //find max value of mat
    for(int r = 0; r < mat.rows; r++)
        for (int c = 0; c < mat.cols; c++)
        {
            float val = mat.pData[ r * mat.cols + c];
            max = ( max > val ? max : val);
        }
    return max;
```

```
struct Matrix
{
    int rows;
    int cols;
    float * pData;
};

float matrix_max(struct Matrix & mat)
{
    float max = FLT_MIN;
    //find max value of mat
    for(int r = 0; r < mat.rows; r++)
        for (int c = 0; c < mat.cols; c++)
        {
            float val = mat.pData[ r * mat.cols + c];
            max = ( max > val ? max : val);
        }
    return max;
```

References as function parameters

To avoid the data is modified by mistakes,

```
float matrix_max(const struct Matrix& mat)
{
    float max = FLT_MIN;
    // ...
    return max;
}
```

Return statement

Statement `return;` is only valid if the function return type is `void`.
Just finish the execution of the function, no value returned.

```
void print_gender(bool isMale)
{
    if(isMale)
        cout << "Male" << endl;
    else
        cout << "Female" << endl;

    return;
}
```

```
void print_gender(bool isMale)
{
    if(isMale)
        cout << "Male" << endl;
    else
        cout << "Female" << endl;
}
```

Return statement

The return type can be a fundamental type or a compound type.
Pass by value:

- Fundamental types: the value of a constant/variable is copied
- Pointers: the address is copied
- Structures: the whole structure is copied

```
float maxa = matrix_max(matA);

Matrix * pMat = create_matrix(4,5);
```

```
Matrix * create_matrix(int rows, int cols)
{
   Matrix * p = new Matrix{rows, cols};
   p->pData = new float[p->rows * p->cols]{1.f, 2.f, 3.f};
   // you should check if the memory is allocated successfully
   // and don't forget to release the memory
   return p;
}
```

If we have a lot to return

Such as a matrix addition function (A+B->C)
A suggested prototype:

- To use references to avoid data copying
- To use const parameters to avoid the input data is modified
- To use non-const reference parameters to receive the output

```cpp
bool matrix_add(const Matrix &matA, const Matrix &matB, Matrix &matC)
{
    // check the dimensions of the three matrices
    // re-create matC if needed
    // do: matC = matA + matB
    // return true if everything is right
}
```

Similar

Matrix add in OpenCV
https://github.com/opencv/opencv/blob/master/modules/core/src/arithm.cpp

https://github.com/opencv/opencv/blob/master/modules/core/src/arithm.cpp

```
void cv::add( InputArray src1, InputArray src2, OutputArray dst,
              InputArray mask, int dtype )
{
    CV_INSTRUMENT_REGION();

    arithm_op(src1, src2, dst, mask, dtype, getAddTab(), false, 0, OCL_OP_ADD );
}
```

`inline` Functions Avoid Function Call Overhead

A function specified as **`inline`** (usually) is expanded “in line” at each call.

inline functions

Stack operations and jumps are needed for a function call.
It is a heavy cost for some frequently called tiny functions.

```
float max_function(float a, float b)
{
    if (a > b)
        return a;
    else
        return b;
}
```

```
int main()
{
    int num1 = 20;
    int num2 = 30;
    int maxv = max_function(num1, num2);


    maxv = max_function(numn, maxv);

}
```

Inline functions

The generated instructions by a compiler can be as follows to improve efficiency

```
int main()
{
    int num1 = 20;
    int num2 = 30;
    int maxv =     {if (num1 > num2)
                         return num1;
                     else
                         return num2;}

    maxv =     {if (numn > maxv)
                     return numn;
                 else
                     return maxv;}
}
```

Inline functions

inline **suggests** the compiler to perform that kind of optimizations.
The compiler may not follow your suggestion if the function is too complex or contains some constrains.
Some functions without inline may be optimized as an inline one.

```
inline float max_function(float a, float b)
{
   if (a > b)
      return a;
   else
      return b;
}
```

Preprocessor macro

```
#define MAX_MACRO(a, b) (a)>(b) ? (a) : (b)
```

The source code will be replaced by a preprocessor.
Surely no cost of a function call,
And `a`, `b` can be any types which can compare.

inline.cpp

Function Signature and Overloading

Signature

Function signature defines the *input types* for a (specialized) function and the *inputs + outputs types* for a template function

A function signature includes the <u>number</u> of arguments, the <u>types</u> of arguments, and the <u>order</u> of the arguments

- The C++ standard prohibits a function declaration that only differs in the return type
- Function declarations with different signatures can have distinct return types

Overloading

Function overloading allows to have distinct functions with the same name but with different *signatures*

Overloaded Functions

Functions that have the same name but different parameter lists and that appear in the same scope are **overloaded**. For example, functions named `print`:

```
void print(const char *cp);
void print(string s);
void print(const int *beg, const int *end);
void print(const int ia[], size_t size);
```

Function Signature and Overloading

```
void f(int a, char* b);          // signature: (int, char*)

// char f(int a, char* b);       // compile error same signature
                                 // but different return types

void f(const int a, char* b);    // same signature, ok
                                 // const int == int

void f(int a, const char* b);    // overloading with signature: (int, const char*)


int f(float);                    // overloading with signature: (float)
                                 // the return type is different
```

Overloading Resolution Rules

- An exact match
- A promotion (e.g. char to int)
- A standard type conversion (e.g. float and int)
- A constructor or user-defined type conversion

```
void f(int   a);
void f(float b);           // overload
void f(float b, char c);   // overload
//----------------------------------------------------------
   f(0);           // ok
// f('a');         // compile error ambiguous match
   f(2.3f);        // ok
// f(2.3);         // compile error ambiguous match
   f(2.3, 'a');    // ok, standard type conversion
```

Function Default Parameters

Default/Optional parameter

A **default parameter** is a function parameter that has a default value

- If the user does not supply a value for this parameter, the default value will be used
- All default parameters must be the rightmost parameters
- Default parameters must be declared only once
- Default parameters can improve compile time and avoid redundant code because they avoid defining other overloaded functions

```
void f(int a, int b = 20);          // declaration

//void f(int a, int b = 10) { ... } // compile error, already set in the declaration

void f(int a, int b) { ... }        // definition, default value of "b" is already set

f(5);  // b is 20
```

Function Default Parameters

```
typedef string::size_type sz; // typedef
string screen(sz ht = 24, sz wid = 80, char backgrnd = ' ');
string window;
window = screen(); // equivalent to screen(24,80,' ')
window = screen(66);// equivalent to screen(66,80,' ')
window = screen(66, 256); // screen(66,256,' ')
window = screen(66, 256, '#'); // screen(66,256,'#')
```