CS100 Lecture 11

C++ Introduction, Strings

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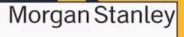
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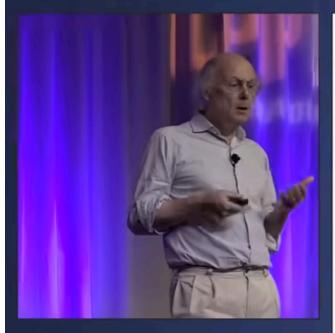
Brief history of C++











Bjarne Stroustrup

C++20: Reaching for the Aims of C++

Video Sponsorship Provided By:



Bell Labs 1979



awk Dennis Ritchie Unix

C++



Innovation = invention + development



Transistors CCDs Fibers



Doug McIlroy



Brian Kernighan



Huge range of interesting technical problems

Stroustrup - CppCon 2021



C with Classes

Back to 1979, the Bell Labs: C with Classes was invented by Bjarne Stroustrup.

- An object-oriented C, with the ideas of "class" from Simula (and several other programming languages).
- Based on C, with many improvements: better type checking, better linkage, ...

The development of C++ also influences that of C.

• Today's C has also deprecated the unsafe function declarations, and has adopted better type checking.

The birth of C++

After C with Classes was seen as a "medium success" by Stroustrup, he moved on to make a better new language - C++ (1983).

C++ is an object-oriented programming language.

C++ is a multi-paradigm programming language that

- is a better C,
- supports data abstraction, and that
- supports object-oriented programming.

Standardization of C++

Standardization: C++98, C++11, C++14, C++17, C++20, C++23, C++26, ...

- C++98: The first ISO standard in 1998.
- C++11: Marks the beginning of modern C++.
- C++14/17: Some slight fixes and improvements of C++11.
- C++20: The first standard that delivers on virtually all the features that Bjarne Stroustrup dreamed of in *The Design and Evolution of C++* in 1994.
 - "D&E Complete"

CS100 is based on C++17.

Overview of C++

What do embedded systems, game development, high frequency trading, and particle accelerators have in common? - C++, of course!

Effective C++ Item 1 (by Scott Meyers): **View C++** as a federation of languages.

The easiest way is to view C++ not as a single language but as a federation of related languages ... Fortunately, there are only four:

- C.
- Object-Oriented C++.
- Template C++.
- The STL.

"Better C"

Safer & more reasonable designs.

- bool, true and false are built-in. No need to #include <stdbool.h>. true and false are of type bool, not int.
- The return type of logical operators &&, ||, ! and comparison operators <,
 <=, >, >= , == , != is bool, not int.
- The type of string literals "hello" is const char [N+1], not char [N+1].
- The type of character literals 'a' is char, not int.

"Better C"

Safer & more reasonable designs.

- Potentially dangerous type conversions are not allowed to happen implicitly. They
 are errors, not just warnings.
- const variables initialized with literals are compile-time constants. They can be used as the length of arrays.
- int fun() declares a function accepting no arguments. It is not accepting unknown arguments.

Basic IO

Hello world

```
C: Use printf

C++: Use std::cout

#include <stdio.h>

int main(void) {
  printf("Hello world\n");
  return 0;
}

int main() { // just an empty `()`
  std::cout << "Hello world\n";
  return 0;
}</pre>
```

Note on the main function: In C++, a function declared with an empty parameter list accepts no arguments, so there is no need to put a void there.

A+B problem

C: C++:

- For input: There is no need to take the address of a and b! C++ has a way to obtain the *reference* of the argument.
- There is no need to write %d! C++ has a way of identifying the type of the argument, and will select the correct way to handle that type.

```
#include <iostream>
int main() {
  int a, b;
  std::cin >> a >> b;
  std::cout << "a + b = " << a + b << '\n';
  return 0;
}</pre>
```

std::cin and std::cout : two objects defined in the standard library file <iostream>.

- They are not functions.
- The input and output "functions" are actually the operators << and >> , which are overloaded to do something different from bit shifting.
 - We will learn about operator overloading in later lectures.

```
#include <iostream>
int main() {
  int a, b;
  std::cin >> a >> b;
  std::cout << "a + b = " << a + b << '\n';
  return 0;
}</pre>
```

std::cin and std::cout : two objects defined in the standard library file <iostream> .

• std::cin stands for standard input stream. std::cout stands for the standard output stream.

std::cin >> x: Reads something and stores it in the variable x.

- x can be of any supported type: integers, floating-points, characters, strings, ...
- C++ has a way of identifying the type of x and selecting the correct way to read it. We don't need the annoying "%d", "%f", ... anymore.
- C++ functions have a way of obtaining the reference of the argument. We don't need to take the address of x.

- std::cin >> x returns std::cin , so we can write several reads in a chained way:
 - o std::cin >> x >> y >> z is equivalent to ((std::cin >> x) >> y) >> z,
 which is equivalent to

```
std::cin >> x;
std::cin >> y;
std::cin >> z;
```

Similarly, outputs can also be chained: std::cout << x << y << z is
 equivalent to

```
std::cout << x;
std::cout << y;
std::cout << z;</pre>
```

Standard library

Standard library file names

The names of C++ standard library files **have no extensions**: <iostream> instead of <iostream.h> , <string> instead of <string.h> .

Namespace std

```
std::cin and std::cout : names from the standard library.
```

C++ has a large standard library with a lot of names declared.

To avoid **name collisions**, all the names from the standard library are placed in a **namespace** named std.

• Example of name collisions in C: Suppose we want to write our own quick-sort:

```
#include <stdlib.h>
void qsort(int *a, int n) { // Ooops! stdlib already has one named `qsort`.
    // ...
}
```

Namespace std

```
std::cin and std::cout : names from the standard library.
```

C++ has a large standard library with a lot of names declared.

To avoid **name collisions**, all the names from the standard library are placed in a **namespace** named std.

- You can write using std::cin; to introduce std::cin into the current scope, so that cin can be used without std::.
- You may write using namespace std; to introduce all the names in std into the current scope, but you will be at the risk of name collisions again.

Compatibility with C standard library

The C++ standard library has everything from the C standard library, **but not exactly the same as in C**.

- For some historical issues, C has many awkward designs and weird defaults, some of which are **not compatible** in C++.
- The C++ version of a C standard library file <xxx.h> is <cxxx>, with all the names also introduced into namespace std.

```
#include <cstdio>
int main() {
  int a, b; std::scanf("%d%d", &a, &b);
  std::printf("%d\n", a + b);
}
```

[Best practice] Use <cxxx> instead of <xxx.h> when you need the C standard library in C++.

std::string

Defined in the standard library file <string> (not <string.h> , not <cstring> !!)

The string.

Define and initialize a string

```
std::string str = "Hello world";
// equivalent: std::string str("Hello world");
// equivalent: std::string str{"Hello world"}; (modern)
std::cout << str << std::endl;</pre>
std::string s1(7, 'a');
std::cout << s1 << std::endl; // aaaaaaa</pre>
std::string s2 = s1; // s2 is a copy of s1
std::cout << s2 << std::endl; // aaaaaaa</pre>
std::string s; // "" (empty string)
```

Default-initialization of a std::string will produce **an empty string**, not indeterminate value and has no undefined behaviors!

Strings

- The memory of std::string is allocated and deallocated automatically.
- We can insert or erase characters in a std::string. The memory of storage will be adjusted automatically.
- std::string does not need an explicit '\0' at the end. It has its way of recognizing the end.
- When you use std::string, pay attention to its contents instead of the implementation details.

Length of a string

Member function s.size()

```
std::string str{"Hello world"};
std::cout << str.size() << std::endl;</pre>
```

Not strlen, not sizeof!!

Member function s.empty()

```
if (str.empty()) {
   // ...
}
```

Concatenation of strings

```
Use + and += directly!
```

- No need to care about the memory allocation.
- No awkward functions like strcat.

```
std::string s1 = "Hello";
std::string s2 = "world";
std::string s3 = s1 + ' ' + s2; // "Hello world"
s1 += s2; // s1 becomes "Helloworld"
s2 += "C++string"; // s2 becomes "worldC++string"
```

Concatenation of strings

At least one operand of + should be std::string.

```
const char *old_bad_ugly_C_style_string = "hello";
std::string good_beautiful_Cpp_string = "hello";
std::string s1 = good_beautiful_Cpp_string + "aaaaaa"; // OK.
std::string s2 = "aaaaa" + good_beautiful_Cpp_string; // OK.
std::string s3 = old_bad_ugly_C_style_string + "aaaaaa"; // Error
```

Is this ok?

```
std::string hello{"hello"};
std::string s = hello + "world" + "C++";
```

Concatenation of strings

At least one operand of + should be std::string.

```
const char *old_bad_ugly_C_style_string = "hello";
std::string good_beautiful_Cpp_string = "hello";
std::string s1 = good_beautiful_Cpp_string + "aaaaaa"; // OK.
std::string s2 = "aaaaa" + good_beautiful_Cpp_string; // OK.
std::string s3 = old_bad_ugly_C_style_string + "aaaaaa"; // Error
```

Is this ok?

```
std::string hello{"hello"};
std::string s = hello + "world" + "C++";
```

```
Yes! + is left-associated. (hello + "world") is of type std::string.
```

Use +=

In C, a = a + b is equivalent to a += b. This is not always true in C++.

For two std::string S s1 and s2, s1 = s1 + s2 is different from s1 += s2.

- s1 = s1 + s2 constructs a temporary object s1 + s2 (so that the contents of s1 are copied), and then assigns it to s1.
- s1 += s2 appends s2 directly to the end of s1, without copying s1.

Try these with n = 1000000:

Lexicographical comparison of strings

```
Just use < , <= , > , >= , == , !=!
```

No loops. No weird functions like strcmp.

Copying a string

Just use =!

```
std::string s1{"Hello"};
std::string s2{"world"};
s2 = s1; // s2 is a copy of s1
s1 += 'a'; // s2 is still "Hello"
```

The copy assignment operator of std::string will copy the contents of it.

 \Rightarrow We will learn about copy assignment operators in later lectures.

String IO

Use std::cin >> s and std::cout << s , as simple as handling an integer.

• Does std::cin >> s ignore leading whitespaces? Does it read an entire line or just a sequence of non-whitespace characters? Do some experiments on it.

std::getline(std::cin, s): Reads a string starting from the current character, and stops at the first '\n'.

• Is the ending '\n' consumed? Is it stored? Do some experiments.

Traversing a string: Use range-based for loops.

Example: Print all the uppercase letters in a string.

```
for (char c : s) // The range-based for loops
  if (std::isupper(c)) // in <cctype>
    std::cout << c;
std::cout << std::endl;</pre>
```

Equivalent way: Use subscripts, which is verbose and inconvenient.

```
for (std::size_t i = 0; i != s.size(); ++i)
  if (std::isupper(s[i]))
    std::cout << s[i];
std::cout << std::endl;</pre>
```

[Best practice] <u>Use range-based</u> <u>for loops. They are modern, clear, simple, generic, and hence more recommended.</u>

⇒ More about range-based for loops in later lectures.

Conversion between strings and arithmetic numbers

For a number x of any arithmetic type, std::to_string(x) returns a string representing it.

```
int ival = 42;
double dval = 3.14;
std::string s = std::to_string(ival) + std::to_string(dval);
std::cout << s << '\n'; // Possible output: 423.140000</pre>
```

std::stoi(s), std::stol(s), ...: Extracts the arithmetic value represented by s.

See this list.

Summary

- IO: Use <iostream>, std::cin >> x >> y, std::cout << x << y.
- Namespace std.
- C++ standard library files: names with no extensions.
- Compatible with C, but use <cxxx> instead of <xxx.h>.

Summary

```
std::string
```

- No need for a terminating '\0'.
- Automatic memory management.
- s.size() returns the length. s.empty() returns whether s is empty.
- Use + and += for concatenation. Use < , <= , > , >= , == , != for comparison.
 Use = for copying.

Summary

```
std::string
```

- Use >> and << for IO, as well as std::getline.
- Use s[i] to access the elements.
- Use range-based for loops to traverse a string.
- Use std::to_string and std::stoi, std::stol, ... for numeric conversions.
- Full list of functions related to std::string:
 https://en.cppreference.com/w/cpp/string/basic_string