CS100 Recitation 11

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A Federation of 4 Languages

Effective C++ Item 1: View C++ as a federation of languages.

- ☑ C
- ☑ Object-Oriented C++
- ☐ Template C++
- ☐ The STL

Operator Overloading

- At least one class-type parameter.
- Cannot change the **precedence** or the **associativity**.

Operators that may be overloaded:

+	-	*	/	%	^
&	|	~	!	,	=
<	>	<=	>=	++	--
<<	>>	==	!=	&&	||
+=	-=	/=	%=	^=	&=
|=	*=	<<=	>>=	[]	()
->	->*	new	new[]	delete	delete[]

Operator Overloading

Operators that may not be overloaded:

```
::   .   .*   ?:
```

Overloaded operator is a function:

- A special name: the `operator` keyword followed by the symbol of the operator.
- Non-member function: Operands are the parameters from left to right.
- Member function: The leftmost operand is implicitly bound to `this`. Other operands are the parameters from left to right.

Operator Overloading

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More Effective C++ Item 7 says that never overload operator `&&`, `||` and `,`. Why?

Operator Overloading

We have seen that

- The IO library overloads `operator<<` and `operator>>`.
- The string library overloads `operator+` and `operator[]`.
  - Why won't '`"ABC" + "DEF"`' compile?

Contents

`iostream`, `cin` and `cout`

- `std::cin`: object of type `std::istream`.
- `std::cout`: object of type `std::ostream`.
- `std::istream` and `std::ostream` are **uncopyable** types.

`iostream`, `cin` and `cout`

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- `std::cout`: object of type `std::ostream`.
- `std::istream` and `std::ostream` are **uncopyable** types.
- Outputs can be chained together as in '`cout << a << b`'. Why?

iostream, cin and cout

- `std::cin`: object of type `std::istream`.
- `std::cout`: object of type `std::ostream`.
- `std::istream` and `std::ostream` are **uncopyable** types.
- Outputs can be chained together as in '`cout << a << b`'. Why?

```
inline std::ostream &operator<<
        (std::ostream &os, const Point2d &p) {
  os << "(" << p.get_x() << ", " << p.get_y() << ")";
  return os;
}
```

Test the State of `iostream`

On input failure, no error would be thrown, but we can test this by using the stream object as a condition.

```
struct Vector2d {
  double x, y, norm_l2;
};
inline std::istream &operator>>
        (std::istream &is, Vector2d &v) {
  is >> v.x >> v.y;
  // On input failure, set the object to a valid state.
  if (is)
    v.norm_l2 = std::sqrt(v.x * v.x + v.y * v.y);
  else
    v = Vector2d{};
  return is;
}
```

Examples

Read an unknown number of integers?

```
std::vector<int> v;
int x;
while (std::cin >> x)
  v.push_back(x);
```

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Read a line as a string?

```
std::string line;
std::getline(std::cin, line);
```

Examples

Read an unknown number of integers?

```
std::vector<int> v;
int x;
while (std::cin >> x)
  v.push_back(x);
```

Read a line as a string?

```
std::string line;
std::getline(std::cin, line);
```

- `std::getline` reads until the first newline character (‘\n’), and throws away that newline character.
- What happens?

```
int n; std::cin >> n;
std::string line;
std::getline(std::cin, line);
```

Manipulators 操纵器

`endl`, `flush` and the like are **manipulators**.

- `endl` outputs a newline character and flushes the buffer.
- `flush` only flushes the buffer.

More manipulators: (some defined in `<iomanip>`)

- `boolalpha`, `noboolalpha`
- `oct`, `hex`, `dec`, `showbase`, `noshowbase`, `setbase`
- `fixed`, `setprecision`, `scientific`
- ......

C++ Primer 17.5

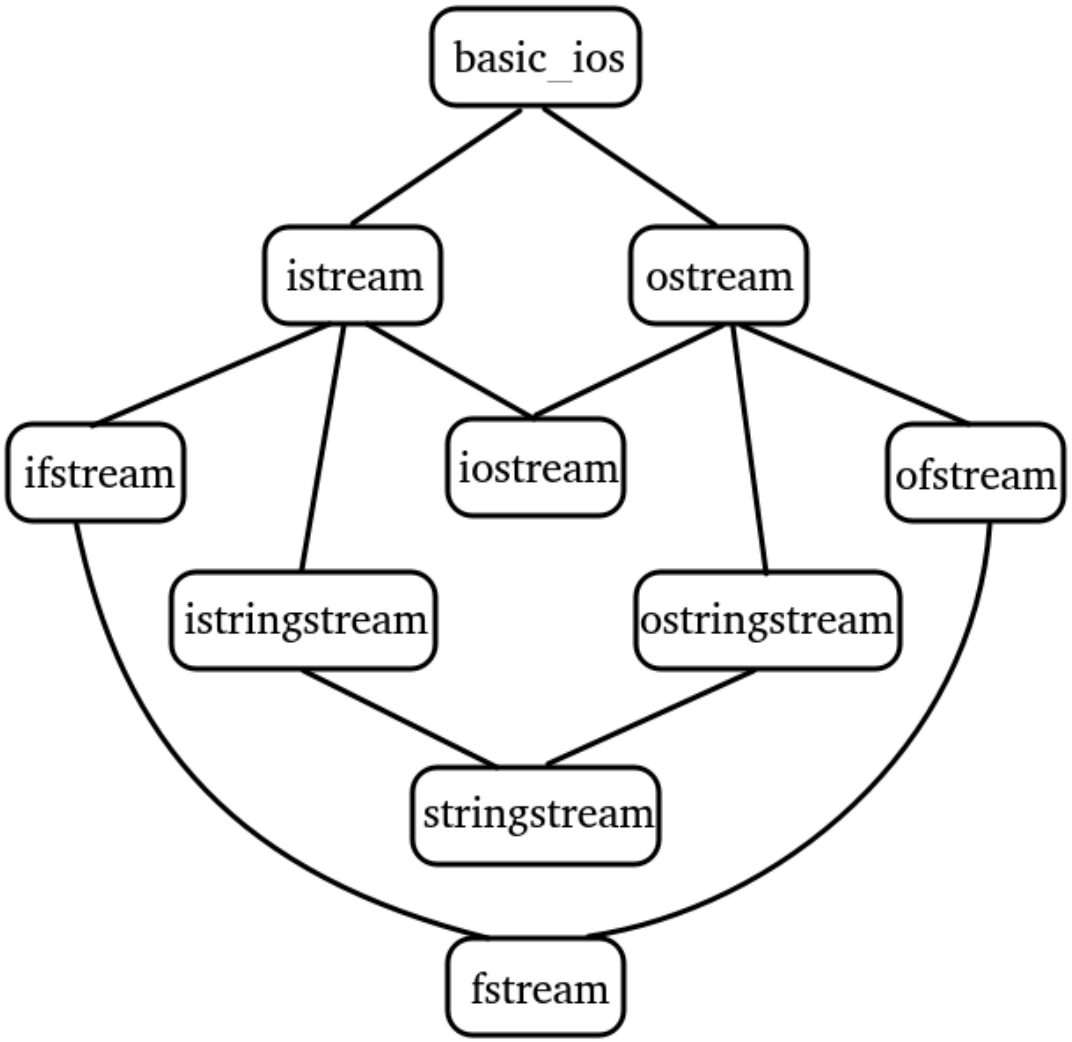
Contents

File Streams

Read an unknown number of integers from a file ‘student_score.txt’?

```
std::ifstream infile("student_score.txt");
// Equivalent way:
// std::ifstream infile;
// infile.open("student_score.txt");
std::vector<int> score;
int x;
while (infile >> x)
  score.push_back(x);
infile.close();
```

Inheritance



- Multiple inheritance
- Virtual inheritance
- What can we know from this?

Real World Example

Read a '.tex' file. Change math from '$...$' to '\(...\)'.

```
std::ifstream infile("hw3.tex");
std::ofstream result("result.tex");
bool in_math = false;
std::string line;
while (std::getline(infile, line)) {
  // process the line
}
infile.close();
result.close();
```

File Modes

Append something to a file, instead of overwriting it?

```
std::ofstream out_file("name.txt", std::ofstream::app);
```

File Modes

Append something to a file, instead of overwriting it?

```
std::ofstream out_file("name.txt", std::ofstream::app);
```

`in`	Open for input
`out`	Open for output
`app`	Seek to the end before every write
`ate`	Seek to the end immediately after the open
`trunc`	Truncate the file
`binary`	Do IO operations in binary mode

- *C++ Primer* 8.2.2

Contents

Stringstreams

Read data from a string, or generate a string by writing different kinds of data.

```
struct Person_info {
  std::string name;
  std::vector<std::string> phones;
};
std::string line;
std::vector<Person_info> people;
while (std::getline(std::cin, line)) {
  Person_info info;
  std::istringstream record(line);
  record >> info.name;
  std::string phone;
  while (record >> phone)
    info.phones.push_back(phone);
  people.push_back(info);
}
```

Stringstreams

Convert some `double` or `int` to a string?

```
inline std::string convert(double value) {
  std::ostringstream oss;
  oss << value;
  return oss.str();
}
```

Stringstreams

Convert some `double` or `int` to a string?

```
inline std::string convert(double value) {
  std::ostringstream oss;
  oss << value;
  return oss.str();
}
```

It works, but `std::to_string` is a better choice!

Contents

Construction

`string s1;`	Default initialization. `s1` contains `""`.
`string s2(s1);`	Copy initialization. `s2` is a copy of `s1`.
`string s2 = s1;`	Equivalent to `string s2(s1)`.
`string s3("hello");`	`s3` is a copy of the string literal.
`string s3 = "hello";`	Equivalent to `string s3("hello")`.
`string s4(n, c);`	Initialize `s4` with `n` copies of a `char c`.

- A string object is **NOT** null-terminated!

IO

`os << s`	Writes `s` onto output stream `os`.
`is >> s`	Reads a string from `is` into `s`.
`getline(is, s)`	Reads a line of input from `is` into `s`.

- `is >> s` starts reading **from the first non-whitespace character**, and reads until the next whitespace character. The whitespace in the end **is not read and still in the stream**.
- `getline(is, s)` starts reading **from the next character** and reads until the first newline character. The newline character is **read, but not stored into `s`, and thrown away**.

Operations

`s.empty()`	Returns `true` iff `s` is empty (`""`).
`s.size()`	Returns the number of characters in `s`.
`s[n]`	Returns a **reference** to the character indexed `n` in `s`.
`s1 + s2`	Returns a `string` that is the concatenation of `s1` and `s2`.
`s1 = s2`	Copy-assignment. Replaces the content in `s1` with a **copy** of `s2`.
`s1 += s2`	Equivalent (?) to `s1 = s1 + s2`.
`==,!=`	Equality and inequality.
`<,<=,>,>=`	Lexicographical-order comparison.

Operations

Concatenation: `s1 + s2`.

- `s1` and `s2` can be a C-style string (`const char *`) or a `char`.
- At least one of `s1` and `s2` should be `std::string`!
- `s + "a" + "b"` compiles, while `"a" + "b" + s` does not compile. Why?

Operations

`s1 += s2` and `s1 = s1 + s2` are **NOT** actually equivalent:

```
auto n = 1000000;
std::string s = "";
for (auto i = 0; i != n; ++i)
  s += "a";
s = "";
for (auto i = 0; i != n; ++i)
  s = s + "a";
```

The first loop takes $O(n)$ time, while the second takes $O\left(n^2\right)$!

- Always prefer compound assignment operators.

Operations

`s.size()` returns a value of the type `std::string::size_type`.

- An unsigned integer type.
- It is guaranteed to be able to store the length of any string.
- It is highly possible that it is `std::size_t`, but not guaranteed.

Operations

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- An unsigned integer type.
- It is guaranteed to be able to store the length of any string.
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`s.length()` is equivalent to `s.size()`, but `s.size()` is preferred. (Why?)

Examples

Example: Convert a nonnegative integer to a string. Add leading zeros.

```
inline std::string convert(int x) {
  auto s = std::to_string(x);
  return std::string(9 - s.size(), '0') + s;
}
```

Examples

Example: Convert a nonnegative integer to a string. Add leading zeros.

```
inline std::string convert(int x) {
  auto s = std::to_string(x);
  return std::string(9 - s.size(), '0') + s;
}
```

Example: Count the number of upper-case letters, and convert them to lower-case.

```
int upper_cnt = 0;
for (decltype(s.size()) i = 0; i != s.size(); ++i)
  if (std::isupper(s[i])) {
    ++upper_cnt;
    s[i] = std::tolower(s[i]);
  }
```

Range-based `for` Loops

Count the number of upper-case letters:

```
int upper_cnt = 0;
for (char c : s)
  if (std::isupper(c))
    ++upper_cnt;
```

Range-based `for` Loops

Count the number of upper-case letters:

```
int upper_cnt = 0;
for (char c : s)
  if (std::isupper(c))
    ++upper_cnt;
```

Convert upper-case letters to lower:

```
for (char &c : s)        // '&' is necessary!
  c = std::tolower(c);
```

Range-based `for` Loops

Count the number of upper-case letters:

```
int upper_cnt = 0;
for (char c : s)
  if (std::isupper(c))
    ++upper_cnt;
```

Convert upper-case letters to lower:

```
for (char &c : s)        // '&' is necessary!
  c = std::tolower(c);
```

- It is common to use `auto` in range-`for`.
- Looks like `Python` `for` loops?

Example

Suppose `s` contains an English sentence. Convert every letter of the first word into upper-case.

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Suppose s contains an English sentence. Convert every letter of the first word into upper-case.

```
for (decltype(s.size()) i = 0;
     i != s.size() && !std::isspace(s[i]); ++i)
  s[i] = std::toupper(s[i]);
```

Example

Suppose s contains an English sentence. Convert every letter of the first word into upper-case.

```
for (decltype(s.size()) i = 0;
     i != s.size() && !std::isspace(s[i]); ++i)
  s[i] = std::toupper(s[i]);
```

Range-for:

```
for (auto &c : s) {
  if (std::isspace(c))
    break;
  c = std::toupper(c);
}
```

Contents

Templated Type

```
std::vector<int> vi;
std::vector<std::string> vs;
std::vector<Widget> vw;
std::vector<std::vector<double>> vvd;
```

- **Instantiation** of a class template
- Template arguments: Must be known at compile-time!
- C++ is statically-typed!

Construction

`vector<T> v1`	Default initialization. `v1` is empty.
`vector<T> v2(v1)`	Copy initialization. `v2` is a copy of `v1`.
`vector<T> v2 = v1`	Equivalent to `vector<T> v2(v1)`.
`vector<T> v3(n, val)`	`v3` contains `n` copies of `val`.
`vector<T> v4(n)`	`v4` contains `n` default-initialized elements.

Every STL container has **value semantics**. Copy of a container will copy every element.

Construction

Since C++11, one more way of construction:

```
vector<T> v5 = {a, b, c, d};
vector<T> v6{a, b, c, d};   // Equivalent way.
```

For example,

```
vector<int> v = {2, 3, 5, 7, 11};
```

Construction

Since C++11, one more way of construction:

```
vector<T> v5 = {a, b, c, d};
vector<T> v6{a, b, c, d};   // Equivalent way.
```

For example,

```
vector<int> v = {2, 3, 5, 7, 11};
```

However, this causes troubles to the widely-used **braced-initialization**:

```
Point2d p{3, 4}; // Call Point2d::Point2d(double, double)
vector<int> v(10, 20); // v has 10 elements, each 20.
vector<int> v{10, 20}; // v has 2 elements: 10, 20.
```

Construction

`string` also supports such initialization.

```
string s1 = {'a', 'b', 'c'}; // s1 is "abc"
string s2(48, 'c'); // s2 is "ccc......c"
string s3{48, 'c'}; // s3 is "0c"
```

Allowing initialization from a braced list is now seen as **an error in the design**. (*Effective Modern C++* Item 7)

- Be careful when using braced initialization for every STL container.
- Avoid such design in your own classes.

Construction

`string` also supports such initialization.

```
string s1 = {'a', 'b', 'c'}; // s1 is "abc"
string s2(48, 'c'); // s2 is "ccc......c"
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```

Allowing initialization from a braced list is now seen as **an error in the design**. (*Effective Modern C++* Item 7)

- Be careful when using braced initialization for every STL container.
- Avoid such design in your own classes.

Empty braces is undoubtedly default initialization. It calls the default constructor.

```
vector<int> v{}; // Equivalent to vector<int> v;
                 // Calls the default constructor.
```

Operations

`v.empty()`	Returns `true` iff `v` is empty.
`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 elmeent indexed `n`.
`v = {a, b, c}`	Replaces the elements in `v` with a copies of `a, b, c`.
`==, !=`	Equaltiy and inequality.
`<, <=, >, >=`	Lexicographical-order comparison.

- `v.size()` returns a value of type `vector<T>::size_type`.
- Compare it with `string`'s operation table.
  - In fact, `string` also supports `push_back`.
- Why doesn't `vector` provide concatenation `operator+`?

Access by Subscript

For containers that supports `operator[]` (`string`, `vector`, ...):

- `operator[]` does not check boundaries.
- Every sequential container that provides `operator[]` also provides the `at` member function. `v.at(n)` will `throw` an exception if `n` is out of range.
- It is the programmer's responsibility to ensure every subscript is valid.

```
std::vector<int> v;
std::cout << v[0] << std::endl; // Error!
```

Range-based `for` Loops

Also works for `vector`:

```
std::vector<int> v = {2, 3, 5, 7, 11, 13};
for (auto &x : v)
  x = x * x;
for (auto x : v)
  std::cout << x << " ";
std::cout << std::endl;
```

Range-based `for` Loops

Never change the size of the container within the range-`for`!

```
for (decltype(v.size()) i = 0; i != v.size(); ++i)
  if (v[i] % 2 == 1)
    v.push_back(v[i]); // ok
for (auto x : v)
  if (x % 2 == 1)
    v.push_back(x); // Probably causes undefined behavior!
```

This rule also applies to `string`, since their way of growing is similar.

Contents

Idea

For an array:

```
for (int i = 0; i != n; ++i)
  do_something(a[i]);
```

For a `vector` or a `string`:

```
for (std::size_t i = 0; i != c.size(); ++i)
  do_something(c[i]);
```

For a linked-list?

Idea

For an array:

```
for (int i = 0; i != n; ++i)
  do_something(a[i]);
```

For a `vector` or a `string`:

```
for (std::size_t i = 0; i != c.size(); ++i)
  do_something(c[i]);
```

For a linked-list?

```
for (Node *p = l.head; p; p = p->next)
  do_something(p->value);
```

Idea


苹果用户桌面:
华为用户桌面:
小红书
小红书ID: 108767203


苹果用户出差:
华为用户出差:
小红书
小红书ID: 108767203

Using Iterators

```
std::vector<int> v = {2, 3, 5, 7, 11, 13};
for (auto it = v.begin(); it != v.end(); ++it)
  *it = *it * *it;
for (auto it = v.begin(); it != v.end(); ++it)
  std::cout << *it << " ";
std::cout << std::endl;
```

- The type of 'it' is `std::vector<int>::iterator`.
- `v.begin()` returns the iterator pointing to the first element.
- `v.end()` returns the **off-the-end** iterator, positioned "one past the end" of the container.
- If the container is empty, we have `v.begin() == v.end()`.

Iterator Operations

The iterator of every container supports these operations:

`*iter`	Returns reference to the element denoted by `iter`.
`iter->mem`	Equivalent to `(*iter).mem`.
`++iter`	Increments `iter` to refer to the next element in the container.
`iter++`	Postfix version. Returns the copy of the original iterator.
`==, !=`	Equal iff both iterators are pointing to the same position.

- Dereferencing or incrementing an off-the-end iterator is undefined behavior.

Examples

Count the number of upper-case letters and convert them to lower-case.

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Count the number of upper-case letters and convert them to lower-case.

```
int upper_cnt = 0;
for (auto it = s.begin(); it != s.end(); ++it) {
  if (std::isupper(*it)) {
    ++upper_cnt;
    *it = std::tolower(*it);
  }
}
```

Examples

Count the number of upper-case letters and convert them to lower-case.

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int upper_cnt = 0;
for (auto it = s.begin(); it != s.end(); ++it) {
  if (std::isupper(*it)) {
    ++upper_cnt;
    *it = std::tolower(*it);
  }
}
```

Convert the first word to upper-case.

Examples

Count the number of upper-case letters and convert them to lower-case.

```
int upper_cnt = 0;
for (auto it = s.begin(); it != s.end(); ++it) {
  if (std::isupper(*it)) {
    ++upper_cnt;
    *it = std::tolower(*it);
  }
}
```

Convert the first word to upper-case.

```
for (auto it = s.begin();
    it != s.end() && !std::isspace(*it); ++it)
  *it = std::toupper(*it);
```

Range-`for`

The range-based `for` loop is treated as traversing using iterators.

```
for (auto x : v)
  do_something(x);
// Equivalent:
for (auto it = v.begin(); it != v.end(); ++it) {
  auto x = *it;
  do_something(x);
}
```

Range-for

```
for (const auto &x : v)
  do_something(x);
// Equivalent:
for (auto it = v.begin(); it != v.end(); ++it) {
  const auto &x = *it;
  do_something(x);
}
```

Range-`for`

```
for (const auto &x : v)
  do_something(x);
// Equivalent:
for (auto it = v.begin(); it != v.end(); ++it) {
  const auto &x = *it;
  do_something(x);
}
```

- Any object that could be traversed using the range-`for` loop must provide `begin()` and `end()`, which return an iterator that supports
  - `operator*`: dereference
  - `operator++`: prefix increment
  - `operator!=`

const_iterator

On a const object, begin() and end() return a different iterator type:

```
inline void print_vector(const std::vector<int> &v) {
  for (auto it = v.begin(); it != v.end(); ++it)
    std::cout << *it << " ";
  std::cout << std::endl;
}
```

- it here is of type vector<int>::const_iterator.
- Dereferencing it returns a reference-to-const, which is not modifiable.
- Since C++11, we have explicit way to obtain const_iterators: The cbegin() and cend() member functions.

Other Iterator Operations

Operations Supported by `vector` and `string` iterators:

`iter + n`	Returns an iterator positioned `n` elements forward.
`iter - n`	Returns an iterator positioned `n` elements backward.
`n + iter`	Equivalent to `iter + n`.
`iter += n`	Equivalent to `iter = iter + n`.
`iter -= n`	Equivalent to `iter = iter - n`.
`iter1 - iter2`	Returns the distance between two iterators.
`<,<=,>,>=`	Relational operators.

- The return-type of `iter1 - iter2` is a **type-alias member** named `difference_type`. e.g. `string::difference_type`. It is a signed integer type.
- `iter1 - iter2` returns the number that when added to `iter2` yields `iter1`.

Relational Operators of Iterators

`<`, `<=`, `>`, `>=`: comparing the positions of two iterators in the container.

- If they are not positioned in the same container, the result is undefined.
- Why did I always use `!=` in the `for` loops?

Relational Operators of Iterators

`<`, `<=`, `>`, `>=`: comparing the positions of two iterators in the container.

- If they are not positioned in the same container, the result is undefined.
- Why did I always use `!=` in the `for` loops?
  - Not all kinds of iterators support `<`, `<=`, `>`, `>=`, but all of them support `==` and `!=`.