

COMP6771

Advanced C++ Programming

Week 2.1

STL Containers

Libraries

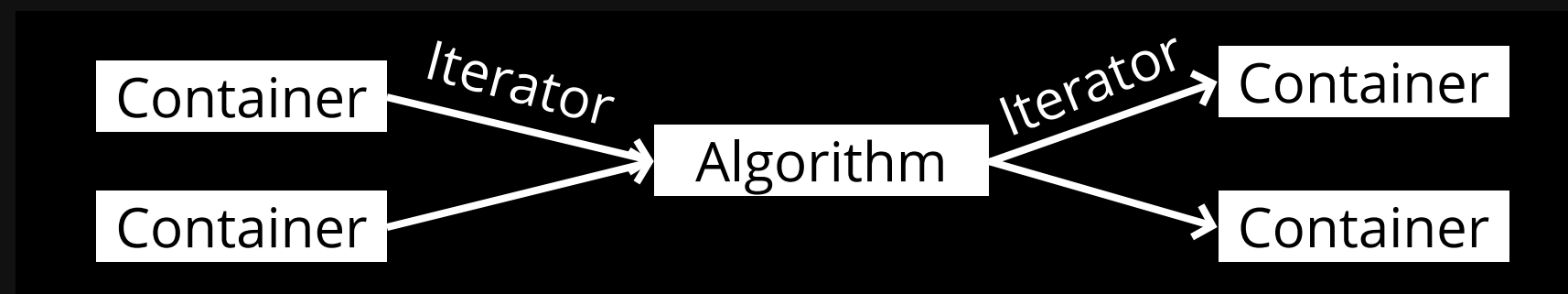
Most of us are quite familiar with libraries in software. For example, in COMP1511, we've used `<stdio.h>` and `<stdlib.h>`.

Being an effective programmer often consists of the effective use of libraries. In some ways, this becomes more important than being a genius at writing code from scratch (Don't reinvent the wheel!).

While there are many libraries that can be used with C++, the Standard Template Library is the one we will focus on.

STL: Standard Template Library

- STL is an architecture and design philosophy for managing generic and abstract collections of data with algorithms
- All components of the STL are templates
- Containers store data, but don't know about algorithms
- Iterators are an API to access items within a container in a particular order, agnostic of the container used
 - Each container has its own iterator types
- Algorithms manipulate values referenced by iterators, but don't know about containers



Iterating through a basic container

```
1 #include <array>
2 #include <iostream>
3
4 int main() {
5     // C-style. Don't do this
6     // int ages[3] = { 18, 19, 20 };
7     // for (int i = 0; i < 3; ++i) {
8     //     std::cout << ages[i] << "\n";
9     // }
10
11     // C++ style. This can be used like any other C++ container.
12     // It has iterators, safe accesses, and it doesn't act like a pointer.
13     std::array<int, 3> ages{ 18, 19, 20 };
14
15     for (unsigned int i = 0; i < ages.size(); ++i) {
16         std::cout << ages[i] << "\n";
17     }
18     for (auto it = ages.begin(); it != ages.end(); ++it) {
19         std::cout << *it << "\n";
20     }
21     for (const auto& age : ages) {
22         std::cout << age << "\n";
23     }
24 }
```

demo201-vec-iter.cpp

Sequential Containers

Organises a finite set of objects into a strict linear arrangement.

`std::vector` Dynamically-sized array.

`std::array` Fixed-sized array.

`std::deque` Double-ended queue.

`std::forward_list` Singly-linked list.

`std::list` Doubly-linked list.

We will explore these in greater detail in Week 10.

It won't be necessary to use anything other than `std::vector` in COMP6771.

Another look at Vector

- Array-like container most used is <vector>
 - Abstract, dynamically resizable array
 - In later weeks we will learn about various ways to construct a vector

```
1 #include <iostream>
2 #include <vector>
3
4 // Begin with numbers 1, 2, 3 in the list already
5 int main() {
6     // In C++17 we can omit the int if the compiler can determine the type.
7     std::vector<int> numbers {1, 2, 3};
8     int input;
9     while (std::cin >> input) {
10         numbers.push_back(input);
11     }
12     std::cout << "1st element: " << numbers.at(0) << "\n"; // slower, safer
13     std::cout << "2nd element: " << numbers[1] << "\n"; // faster, less safe
14     std::cout << "Max size before realloc: " << numbers.capacity() << "\n";
15     for (int n : numbers) {
16         std::cout << n << "\n";
17     }
18 }
```

Ordered Associative Containers

Provide fast retrieval of data based on keys. The keys are sorted. A **value** is accessed via a **key**.

<code>std::set</code>	A collection of unique keys.
<code>std::multiset</code>	A collection of keys.
<code>std::map</code>	Associative array that map a unique keys to values.
<code>std::multimap</code>	Associative array where one key may map to many values.

They are mostly interface-compatible with the unordered associative containers.

std::map example

```
1 #include <iostream>
2 #include <map>
3 #include <string>
4
5 int main() {
6     std::map<std::string, double> m;
7     // The insert function takes in a key-value pair.
8     std::pair<std::string, double> p1{"bat", 14.75};
9     m.insert(p1);
10    // The compiler will automatically construct values as
11    // required when it knows the required type.
12    m.insert({"cat", 10.157});
13    // This is the preferred way of using a map
14    m.emplace("cat", 10.157);
15
16    // This is very dangerous, and one of the most common causes of mistakes in C++.
17    std::cout << m["bat"] << '\n';
18
19    auto it = m.find("bat"); // Iterator to bat if present, otherwise m.end()
20
21    // This is a great example of when to use auto, but we want to show you what type it is.
22    for (const std::pair<const std::string, double>& kv : m) {
23        std::cout << kv.first << ' ' << kv.second << '\n';
24    }
25 }
```

demo203-map.cpp

Unordered Associative Containers

Provide fast retrieval of data based on keys. The keys are hashed.

`std::unordered_set` A collection of unique keys.

`std::unordered_map` Associative array that map unique keys to a values.

Container Performance

- Performance still matters
- STL containers are abstractions of common data structures
- cppreference has a summary of them [here](#).
- Different containers have different time complexity of the same operation (see right)

Operation	vector	list	queue
container()	$O(1)$	$O(1)$	$O(1)$
container(size)	$O(1)$	$O(N)$	$O(1)$
operator[]()	$O(1)$	-	$O(1)$
operator=(container)	$O(N)$	$O(N)$	$O(N)$
at(int)	$O(1)$	-	$O(1)$
size()	$O(1)$	$O(1)$	$O(1)$
resize()	$O(N)$	-	$O(N)$
capacity()	$O(1)$		
erase(iterator)	$O(N)$	$O(1)$	$O(N)$
front()	$O(1)$	$O(1)$	$O(1)$
insert(iterator, value)	$O(N)$	$O(1)$	$O(N)$
pop_back()	$O(1)$	$O(1)$	$O(1)$
pop_front()		$O(1)$	$O(1)$
push_back(value)	$O(1)+$	$O(1)$	$O(1)+$
push_front(value)		$O(1)$	$O(1)+$
begin()	$O(1)$	$O(1)$	$O(1)$
end()	$O(1)$	$O(1)$	$O(1)$

$O(1)+$ means amortised constant time

Feedback

