COMP6771

🍓 STL Containers

Lecture 2.1

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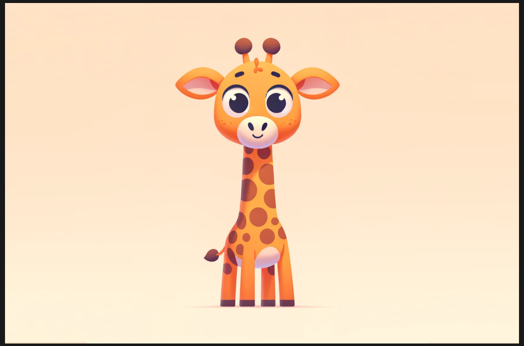

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⚖️ STL: Standard Template Library

- 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

🏃 Basic Container Iteration

```cpp
#include <array>
#include <iostream>

int main()
{
    // C-style. Don't do this
    // int ages[3] = { 18, 19, 20 };
    // for (int i = 0; i < 3; ++i) {
    //   std::cout << ages[i] << "\n";
    // }

    // C++ style. This can be used like any other C++ container.
    // It has iterators, safe accesses, and it doesn't act like a pointer.
    std::array<int, 3> ages { 18, 19, 20 };

    for (unsigned int i = 0; i < ages.size(); ++i) {
        std::cout << ages[i] << "\n";
    }
    for (auto it = ages.begin(); it != ages.end(); ++it) {
        std::cout << *it << "\n";
    }
    for (const auto& age : ages) {
        std::cout << age << "\n";
    }
}
```

vector-iterate.cpp

📦 Sequential Containers

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

`std::vector`	Dynamically-sized array
`std::array`	Fixed-size 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.

📦 Sequential Containers

`<vector>`: Most commonly used array-like container

- Abstract, dynamically-resizable array
- In lalter weeks we will learn about various ways to construct a vector

```cpp
#include <iostream>
#include <vector>

// Begin with numbers 1, 2, 3 in the list already
int main()
{
    // In C++17 we can omit the int if the compiler can determine the type.
    std::vector<int> numbers { 1, 2, 3 };
    int input;
    while (std::cin >> input) {
        numbers.push_back(input);
    }
    std::cout << "1st element: " << numbers.at(0) << "\n"; // slower, safer
    std::cout << "2nd element: " << numbers[1] << "\n"; // faster, less safe
    std::cout << "Max size before realloc: " << numbers.capacity() << "\n";
    for (int n : numbers) {
        std::cout << n << "\n";
    }
}
```

vector-object.cpp

📕 Ordered Associative Containers

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

`std::set`	A collection of unique keys
`std::multiset`	A collection of keys
`std::map`	Associative array that map a unique keys to values
`std::multimap`	Associative array where one key may map to many values

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

📕 Ordered Associative Containers

`std::map` example

```cpp
#include <iostream>
#include <map>
#include <string>

int main()
{
    std::map<std::string, double> m;
    // The insert function takes in a key-value pair.
    std::pair<std::string, double> p1 { "bat", 14.75 };
    m.insert(p1);
    // The compiler will automatically construct values as
    // required when it knows the required type.
    m.insert({ "cat", 10.157 });
    // This is the preferred way of using a map
    m.emplace("cat", 10.157);

    // This is very dangerous, and one of the most common causes of mistakes in C++.
    std::cout << m["bat"] << '\n';

    auto it = m.find("bat"); // Iterator to bat if present, otherwise m.end()
    (void)it;

    // This is a great example of when to use auto, but we want to show you what type it is.
    for (const std::pair<const std::string, double>& kv : m) {
        std::cout << kv.first << ' ' << kv.second << '\n';
    }
}
```

map-container.cpp

🧩 Unordered Associative Containers

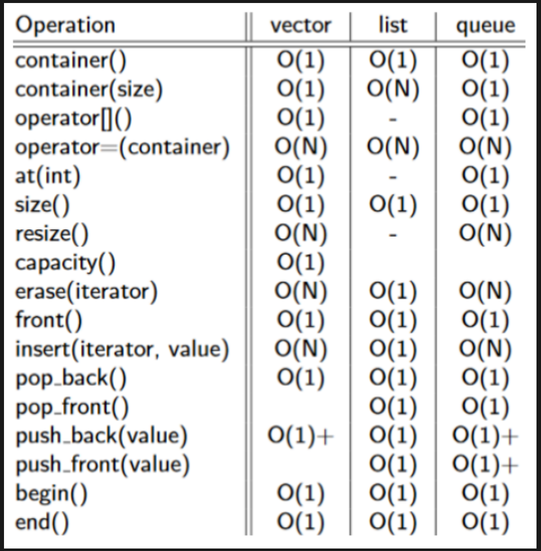
Provide fast retrieval of data based on keys. The keys are hashed.

`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)

Container Performance



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

Or go to the form here.