COMP6771

🍓 STL Algorithms

Lecture 2.3

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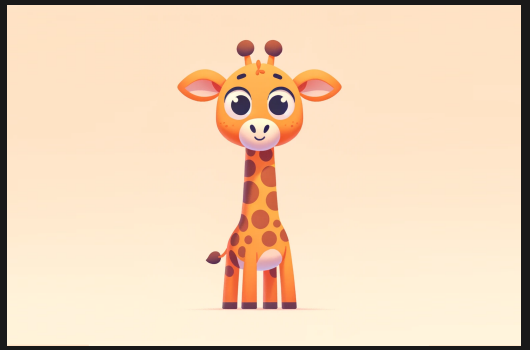

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🐍 STL Algorithms

- STL Algorithms are functions that execute an algorithm on an abstract notion of an iterator.
- In this way, they can work on a number of containers as long as those containers can be represented via a relevant iterator.

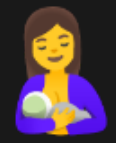
 Simple Example

What's the best way to sum a vector of numbers?

C-Style?

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

int main()
{
    std::vector<int> nums { 1, 2, 3, 4, 5 };

    auto sum = 0;
    for (auto i = 0; i <= static_cast<int>(nums.size()); ++i) {
        sum += i;
    }

    std::cout << sum << "\n";
}
```

c-sum.cpp

 Simple Example

What's the best way to sum a vector of numbers?

Via an iterator? Or for-range?

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

int main()
{
    std::vector<int> nums { 1, 2, 3, 4, 5 };

    auto sum = 0;
    for (auto it = nums.begin(); it != nums.end(); ++it) {
        sum += *it;
    }
    std::cout << sum << "\n";
}
```

simple-sum1.cpp

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

int main()
{
    std::vector<int> nums { 1, 2, 3, 4, 5 };

    int sum = 0;

    // Internally, this uses begin and end,
    // but it abstracts it away.
    for (const auto& i : nums) {
        sum += i;
    }

    std::cout << sum << "\n";
}
```

simple-sum2.cpp

Simple Example

What's the best way to sum a vector of numbers?

Via use of an STL Algorithm

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

int main()
{
    std::vector<int> nums { 1, 2, 3, 4, 5 };
    int sum = std::accumulate(nums.begin(), nums.end(), 0);
    std::cout << sum << "\n";
}
```

sum-stl.cpp

🤱 Simple Example

This is what goes on under the hood

```
/*
template <typename T, typename Container>
T sum(iterator_t<Container> first, iterator_t<Container> last) {
  T total;
  for (; first != last; ++first) {
    total += *first;
  }
  return total
}
*/
```

sum-stl-underlying.cpp

🐷 More Examples

We can also use algorithms to:

- Find the product instead of the sum
- Sum only the first half of elements

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

int main()
{
    std::vector<int> v { 1, 2, 3, 4, 5 };
    int sum = std::accumulate(v.begin(), v.end(), 0);

    // What is the type of std::multiplies<int>()
    int product = std::accumulate(v.begin(), v.end(), 1, std::multiplies<int>());
    (void)product; // dummy line

    auto midpoint = v.begin() + static_cast<int>(v.size() / 2);
    // This looks a lot harder to read. Why might it be better?

    auto midpoint11 = std::next(v.begin(), std::distance(v.begin(), v.end()) / 2);
    (void)midpoint11;

    int sum2 = std::accumulate(v.begin(), midpoint, 0);

    std::cout << sum << " " << sum2 << "\n";
}
```

algos.cpp

🐷 More Examples

We can also use algorithms to:

- Check if an element exists

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

int main()
{
    std::vector<int> nums { 1, 2, 3, 4, 5 };

    auto it = std::find(nums.begin(), nums.end(), 4);

    if (it != nums.end()) {
        std::cout << "Found it!"
                  << "\n";
    }
}
```

find.cpp

 Performance & Portability

- Consider:
  - Number of comparisons for binary search on a vector is O(log N)
  - Number of comparisons for binary search on a linked list is O(N log N)
  - The two implementations are completely different
- We can call the same function on both of them
  - It will end up calling a function have two different overloads, one for a forward iterator, and one for a random access iterator
- Trivial to read
- Trivial to change the type of a container

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

int main()
{
    // Lower bound does a binary search, and returns the first value >= the argument.
    std::vector<int> sortedVec { 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 };
    (void)std::lower_bound(sortedVec.begin(), sortedVec.end(), 5);

    std::list<int> sortedLinkedList { 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 };
    (void)std::lower_bound(sortedLinkedList.begin(), sortedLinkedList.end(), 5);
}
```

bound.cpp

🗑️ Output Sequence Algorithms

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

char to_upper(unsigned char value)
{
    return static_cast<char>(std::toupper(static_cast<unsigned char>(value)));
}

int main()
{

    std::string s = "hello world";
    // Algorithms like transform, which have output iterators,
    // use the other iterator as an output.
    auto upper = std::string(s.size(), '\0');
    std::transform(s.begin(), s.end(), upper.begin(), to_upper);
}
```

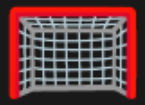
transform.cpp

🗑️ Back Inserter

Gives you an output iterator for a container that adds to the end of it

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

char to_upper(char value)
{
    return static_cast<char>(std::toupper(static_cast<unsigned char>(value)));
}

int main()
{

    std::string s = "hello world";
    // std::for_each modifies each element
    std::for_each(s.begin(), s.end(), toupper);

    std::string upper;
    // std::transform adds to third iterator.
    std::transform(s.begin(), s.end(), std::back_inserter(upper), to_upper);
}
```

inserter.cpp

 Lambda Functions

- A function that can be defined inside other functions
- Can be used with `std::function<ReturnType(Arg1, Arg2)>` (or auto)
  - It can be used as a parameter or variable
  - No need to use function pointers anymore

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

int main()
{
    std::string s = "hello world";
    // std::for_each modifies each element
    std::for_each(s.begin(), s.end(), [](char& value) { value = static_cast<char>(std::toupper(value)); });
}
```

lambda1.cpp

 Lambda Functions

- Anatomy of a lambda function
- Lambdas can be defined anonymously, or they can be stored in a variable

```
[](card const c) -> bool {
  return c.colour == 4;
}
```

```
[capture] (parameters) -> return {
    body
}
```

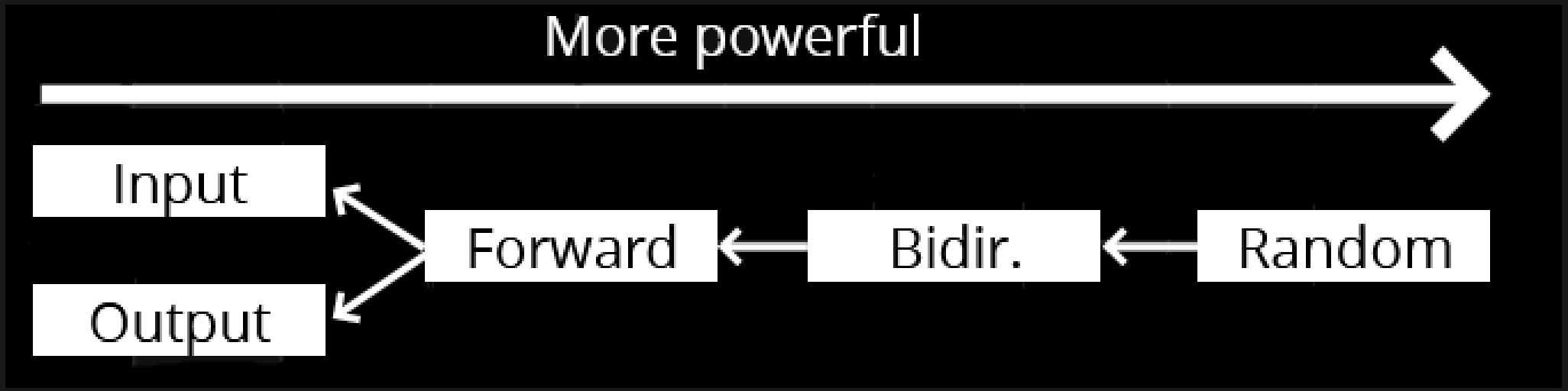
 Lambda Functions

- This doesn't compile
- The lambda function can get access to the scope, but does not by default
- The scope is accessed via the capture []

```
 1 #include <iostream>
 2 #include <vector>
 3
 4 void add_n(std::vector<int>& v, int n) {
 5   std::for_each(v.begin(), v.end(), [n] (int& val) { val = val + n; });
 6 }
 7
 8 int main() {
 9   std::vector<int> v{1,2,3};
10   add_n(v, 3);
11 }
```

😄 Iterator Categories

Operation	Output	Input	Forward	Bidirectional	Random Access
Read		`=*p`	`=*p`	`=*p`	`=*p`
Access		`*p`	`*p`	`*p`	`*p []`
Write	`*p=`		`*p=`	`*p=`	`*p=`
Iteration	`++`	`++`	`++`	`++ --`	`++ -- + - += -=`
Compare		`== !=`	`== !=`	`=== !=`	`== != < > <= >=`



😄 Iterator Categories

An **algorithm** requires certain kinds of iterators for their operations

- **input**: find(), equal()
- **output**: copy()
- **forward**: replace(), binary_search()
- **bi-directional**: reverse()
- **random**: sort()

A **container's** iterator falls into a certain category

- **forward**: forward_list
- **bi-directional**: map, list
- **random**: vector, deque

stack, **queue** are container adapters, and do not have iterators

🦻 Feedback

Or go to the form here.