C++ Standard Template Library (STL)

CSCI 1061U — Programming Workshop 2

faisal.qureshi@uoit.ca
Faculty of Science
University of Ontario Institute of Technology

STL

- Containers
  - Sequential containers
  - Associative containers
  - Container adapters
- Generic algorithms
- Iterators
  - Reverse iterators
  - Const and non-const (mutable) iterators

Sequential Containers

- Sequential containers are class that can be used for storing other items
  - DynamicArray — **std**::vector<T>
  - LinkedList — **std**::list<T>
  - Deques — **std**::deque<T>

Sequential Containers

Allocating a vector of int

```
#include <vector>
std::vector<int>
```

Allocating a list of strings

```
#include <list>
#include <string>
std::vector<std::string>
```

Allocating a deque of vectors of strings

```
#include <deque>
#include <vector>
#include <string>
std::deque<std::vector<std::string> >
```

Iterators

- C++ STL containers (both sequential and associative) define “helper classes,” called *iterators,* to help iterate over each item in the container.

Iterator Example

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

int main()
{
  std::vector<int> v;
  v.push_back(1);
  v.push_back(2);
  v.push_back(3);

  std::vector<int>::iterator i;
  for (i = v.begin(); i != v.end(); ++i) {
    std::cout << *i << std::endl;
  }

  return 0;
}
```

iterator i is a pointer to an element stored in the container

Array Traversal

```
#include <iostream>

int main()
{
  int a[] = {1, 3, 5, 7, 9};

  for (int i=0; i<5; ++i) {
    std::cout << a[i] << std::endl;
  }

  return 0;
}
```

Case 1

```
#include <iostream>

int main()
{
  int a[] = {1, 3, 5, 7, 9};

  for (int* i = &a[0]; i != &a[4]; ++i) {
    std::cout << *i << std::endl;
  }

  return 0;
}
```

Case 2

`std::set<T>`

- Implements sets, each value can only occur once
- Efficient at testing membership O(log n)
  - Use `find()` method
- The value type must have < operator
- Iterator is available
- Addition, deletion is supported

Iterators

- Iterator variable has the same semantics as a pointer to the stored element
- Deference (use operator *) to get the actual value

Iterators

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

int main()
{
  std::vector<int> v;
  v.push_back(1);
  v.push_back(2);
  v.push_back(3);

  std::vector<int>::iterator i;
  for (i = v.begin(); i != v.end(); ++i) {
    std::cout << *i << std::endl;
  }

  return 0;
}
```

Currently it points to nothing

Last element in the container

No points to the first element in the container

Reverse Iterator

```
#include <iostream>
#include <list>
using namespace std;

int main()
{
  list<string> names;
  names.push_back("john");
  names.push_back("amanda");

  list<string>::reverse_iterator i;
  for (i = names.rbegin(); i != names.rend(); ++i) {
    cout << *i << endl;
  }

  return 0;
}
```

Iterators

Different kinds of iterator

```
std::vector<int>::iterator
std::vector<int>::reverse_iterator
std::vector<int>::const_iterator
std::vector<int>::const_reverse_iterator
```

Methods for initializing and checking iterators

```
begin(), end()
cbegin(), cend()
rbegin(), rend()
crbegin(), crend()
```

Containers

- Sequential containers are class that can be used for storing other items
  - DynamicArray — **std**::vector<T> O(1)
  - LinkedList — **std**::list<T> O(n)
  - Deques — **std**::deque<T> O(1)

Accessing element i

Containers

- Sequential containers are class that can be used for storing other items
  - DynamicArray — **std**::vector<T>
  - LinkedList — **std**::list<T>
  - Deques — **std**::deque<T>

	Adding an element
DynamicArray — **std**::vector<T>	End
LinkedList — **std**::list<T>	Anywhere
Deques — **std**::deque<T>	Both ends

Containers

- Sequential containers are class that can be used for storing other items
  - DynamicArray — **std**::vector<T> O(n)
  - LinkedList — **std**::list<T> O(1)
  - Deques — **std**::deque<T> O(n)

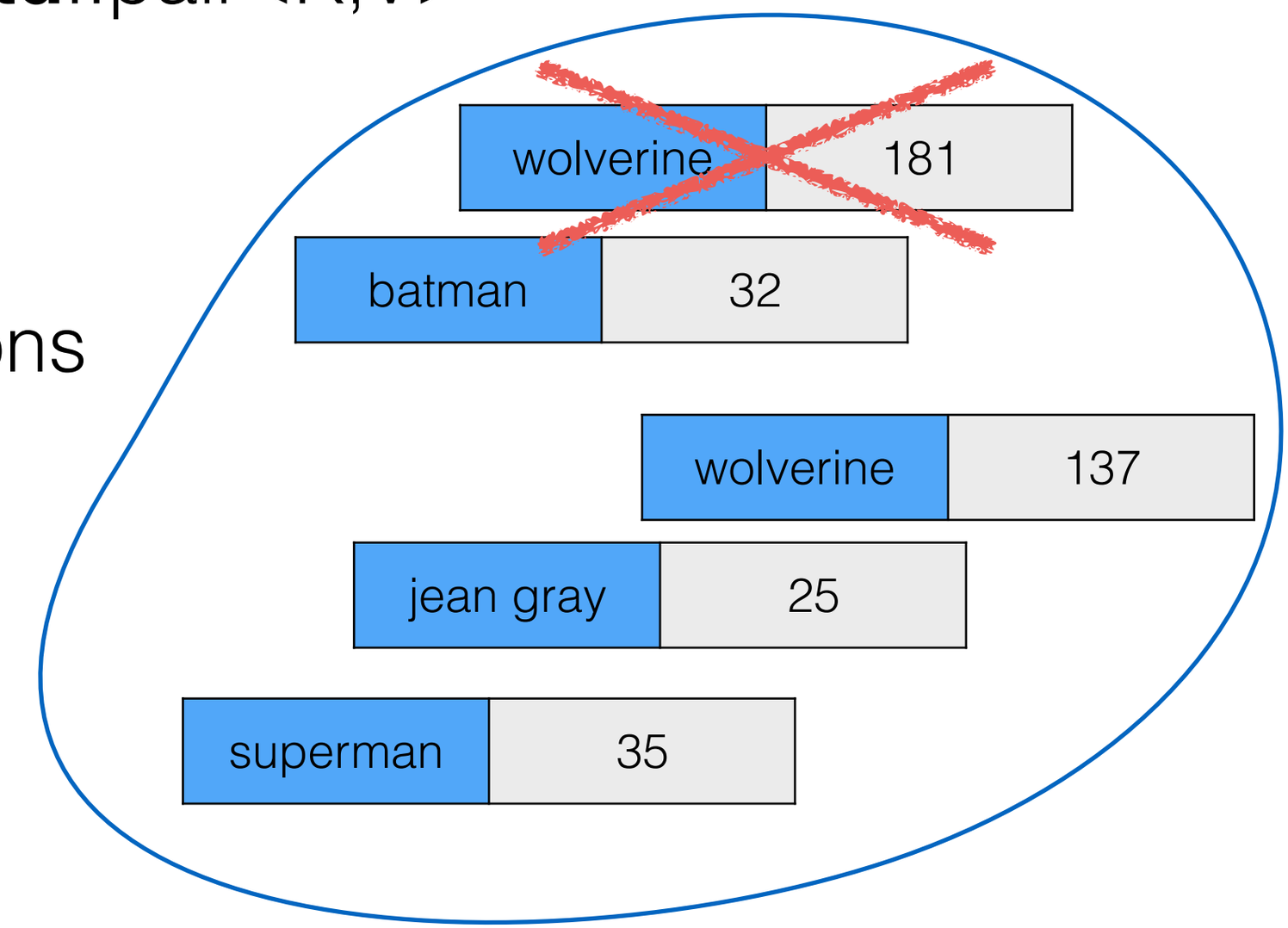
Deleting an element

Associative Containers

- Sequential arrays provide no *meaningful* way to index the stored data
- Example
  - std::vector index elements with integers ***0, 1, 2, ...*** that may have no relationship to the stored data
- It would be nice if we can do the following
  - `ages[“earth”] = 4530000000;`
  - `cout << lastnames[“John”] << endl;`

Associative Container **std**::map<K,V>

- Store (key, value) **std**::pair<K,V>
- Unique key
- Supported operations
  - insertion
  - removal
  - lookup



No specific order (no element 0)

```
#include <map>
#include <iostream>
#include <string>
using namespace std;

int main()
{
  map<string, int> super_heros;

  super_heros["batman"] = 32;
  super_heros["wolverine"] = 137;
  super_heros["jean gray"] = 25;
  super_heros["superman"] = 35;

  map<string, int>::iterator i;
  for (i = super_heros.begin(); i != super_heros.end(); ++i)
  {
    cout << "Age of " << i->first << " is " << i->second << endl;
  }

  return 0;
}
```

Iterators are still available

```
#include <map>
#include <iostream>
#include <string>
using namespace std;

int main()
{
  map<string, int> super_heros;

  super_heros["batman"] = 32;
  super_heros["wolverine"] = 137;
  super_heros["jean gray"] = 25;
  super_heros["superman"] = 35;

  map<string, int>::iterator i = super_heros.find("batman");
  if (i != super_heros.end()) {
    cout << "Batman is " << i->second << endl;
  }

  return 0;
}
```

Associative Container **std**::map<K,V>

- Maps are sometimes referred to as *hashes* or *dictionaries*

- **Key** type should have < operator
  - Use std::string and not char[]

- **Value** type should have default constructor

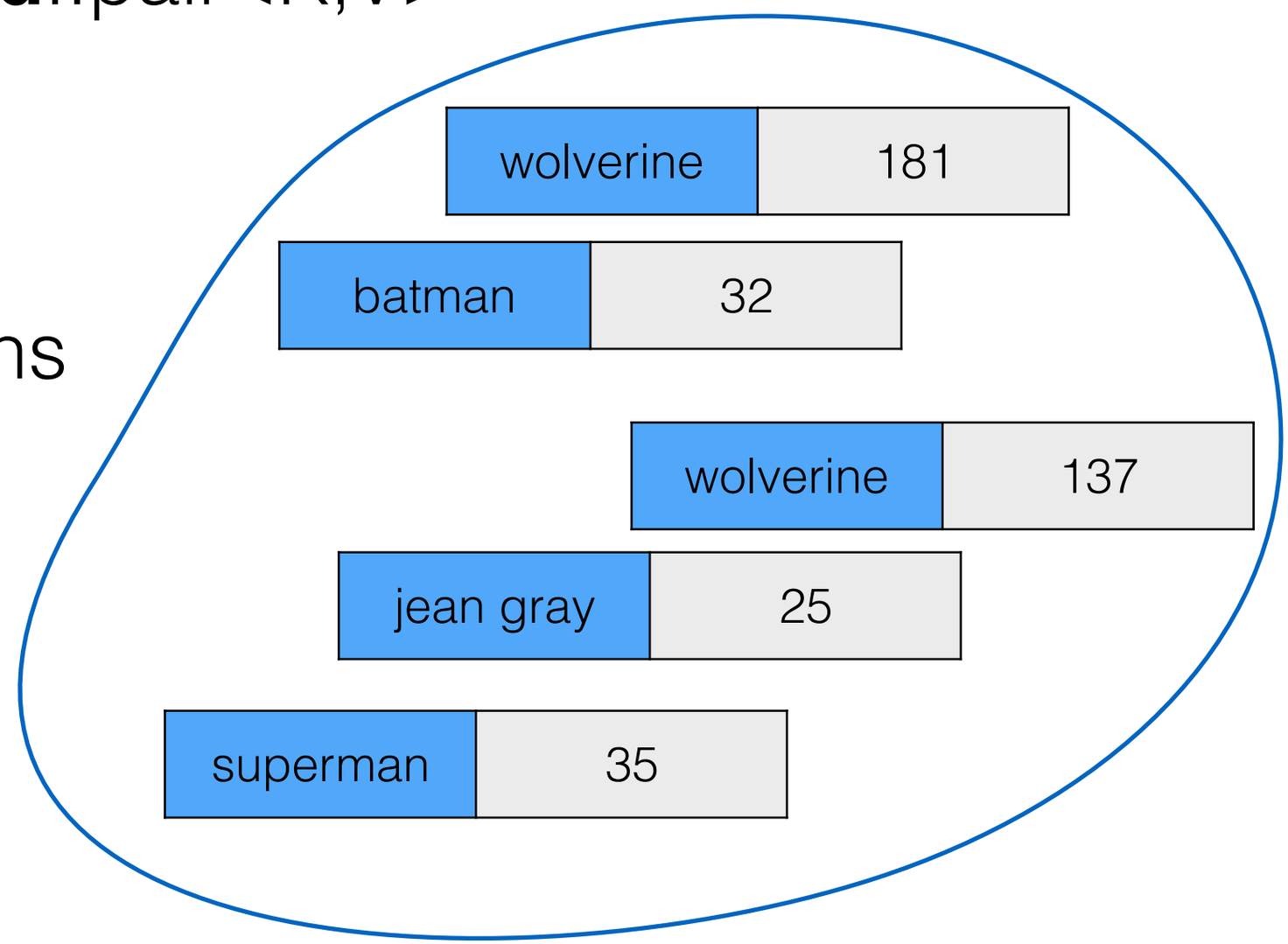
- Provides [ ] operator for both insertion and retrieval

Associative Container **std**::map<K,V>

- Efficient key lookup O(log n)
- Use `find()` function for key lookup
  - Returns an iterative to the (key,value) pair if the key is found
  - Otherwise returns an iterator equal to `end()`

Associative Container **std**::multimap<K,V>

- Store (key, value) **std**::pair<K,V>
- ~~Unique key~~
- Supported operations
  - insertion
  - removal
  - lookup



No specific order (no element 0)

Container Adaptors

- Container adapters are template classes that are implemented “on top of” other classes
  - **std**::stack
  - **std**::queue
  - **std**::priority_queue

Container Adapters

- Adapter template classes have “default” *underlying containers*
  - std::stack is implemented using std::deque
- It is possible to specify a different underlying container
  - **std**::stack<int, **std**::vector<int> >

Algorithms

- Strives to be optimally efficient
- Non-modifying sequence algorithms
- Modifying algorithms

Non-modifying Sequence Algorithms

- Template functions operate on containers
- Does not modify the content of that container
- Example
  - **std**::find()

Modifying Sequence Algorithms

- STL functions that can change the content of a container
- Adding or removing elements from a container may invalidate an iterator
- `std::list` guarantees that no iterator will be changed
- `std::vector` and `std::deque` do not provide any guarantees

STL Algorithms

http://en.cppreference.com/w/cpp/algorithm

c++11: ranged for with containers

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

using namespace std;

int main()
{
  map<int, string> persons = {{10, "Walker"}, {43, "Judy"}};
  for (auto i : persons) {
    cout << "id = " << i.first << " name = " << i.second << endl;
  }

  return 0;
}
```

Compile as follows

```
g++ -std=c++11 ranged-for.cpp
```