Associative Containers & Iterators

Cristian Cibils
(ccibils@stanford.edu)

Recap of Sequence Containers

- Sequence containers store data stored in order
- STL and Stanford sequence containers are similar but have a few key differences

Associative Containers

- Like Sequence Containers, Associative containers store data
- Unlike Sequence Containers, Associative containers have no idea of an ordering
- Instead, based on a **key**
- We will look at a few Associative Containers today
  - Map
  - Set

STL <map>

- Methods are the same as the Stanford Map except for some syntax differences
  - If you want to see a complete list of methods, google search std::map or check out http://www.cplusplus.com/reference/map/map
- Let's see an example using a map (Map.pro)

STL <set>

- Methods are the same as the Stanford Set except for some syntax differences
  - If you want to see a complete list of methods, google search std::set or check out http://www.cplusplus.com/reference/set/set/
- Let's see an example using a set (Set.pro
- Key point, a set is just a specific case of a map

Announcements

- Reminder: Assignment 1 due next Tuesday at midnight

Iterators

- How do we iterate over associative containers?

Iterators

- How do we iterate over associative containers?
  - Not an easy question to answer
  - We first need to look at some history of C++

Versions of C++

- 1983-1998: Prehistoric C++
  - This was the original form of C++. There was no document describing what C++ was. Any code which would compile and run was valid C++
  - This was fine, but many people wanted a standard
- 1998: C++98
  - The C++98 standard is published, which details exactly what valid C++ code is.
- 2003: C++03
  - Minor changes to the rules governing how programs run, but effectively the same as C++98

Versions of C++

- 2011: C++11!
  - C++11 was the largest change to the C++ language since its creation
  - Clarified a lot of things in the old standard
  - Added **tons** of new features
    - Multithreading and atomic types
    - Type inference
    - Lambdas
    - Range based for
    - `constexpr`
    - New initialization syntax
  - Long story short, C++11 has a lot of cool stuff in it!

Versions of C++

C++03	C++11

`map<string, int> map;`
 	
`map<string, int>::iterator i;`
`map<string, int>::iterator end`
`  = map.end();`
 	
`for( i = address_book.start();`
`     i != end; ++i) {`
`    cout  << (*i).first`
`          << " " << (*i).second`
`          << endl;`
`}`
	`map<string, int> map;`
	
	`for (auto& a : map) {`
	`    cout  << a.first << " "`
	`          << a.second << endl;`
	`}`

Versions of C++

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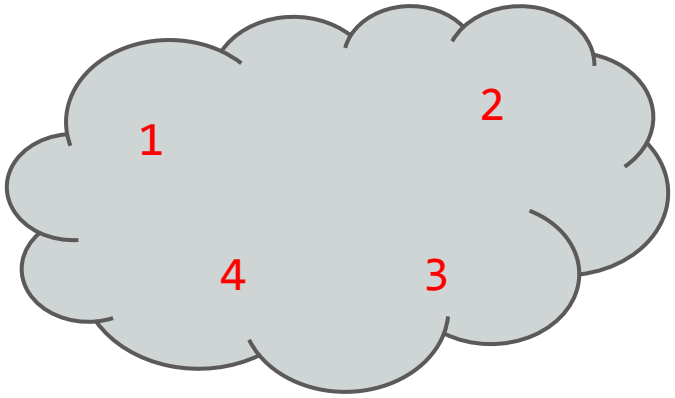
- If we have C++11, why learn about iterators?
  - Not all compilers support C++11
  - Iterators are used for more than just iterating as we will see when we start talking about ranges today and algorithms next week

Iterators

Iterators allow a programmer to iterate over all the values in any container whether it is ordered or not

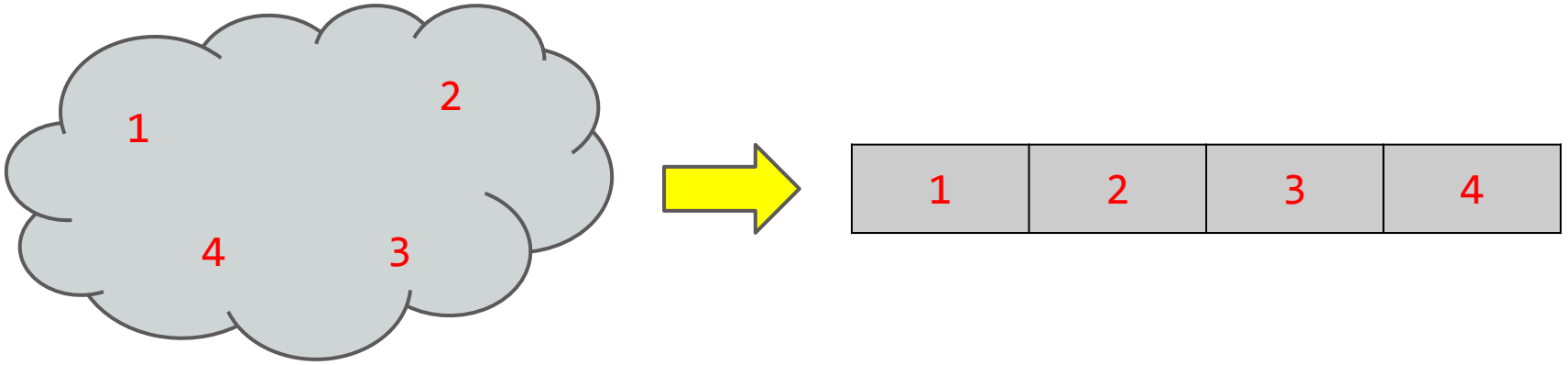
Iterators

- Let's first try and get a conceptual model of what an iterator is
- Say that we have a set of integers called mySet



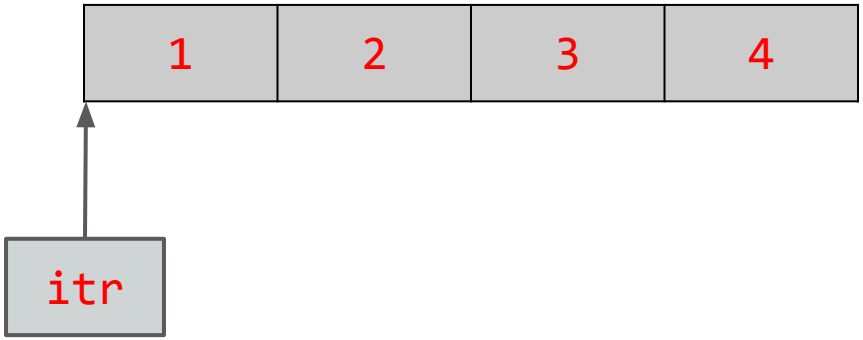
Iterators

- Let's first try and get a conceptual model of what an iterator is
- Iterators allow us to view a non-linear collection in a linear manner



Iterators

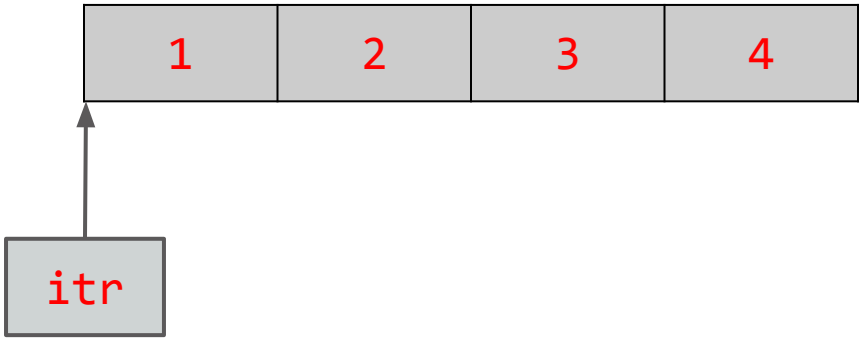
- Let's first try and get a conceptual model of what an iterator is
- We can construct an iterator 'itr' to point to the first element in the set




```
set<int>::iterator itr = mySet.begin();
```

Iterators

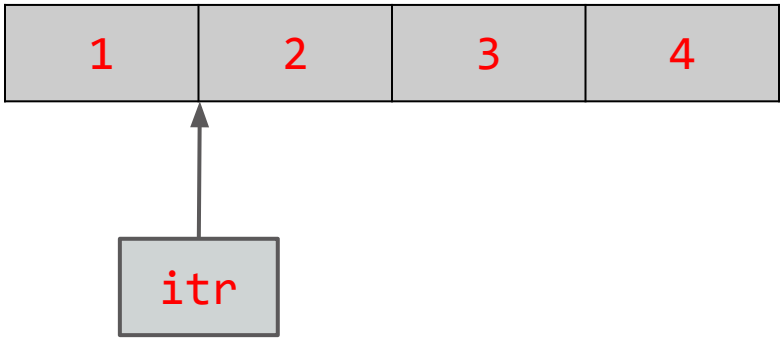
- Let's first try and get a conceptual model of what an iterator is
- We can get the value of an iterator by using the **dereference** operator *




```
cout << *itr << endl; //prints 1
```

Iterators

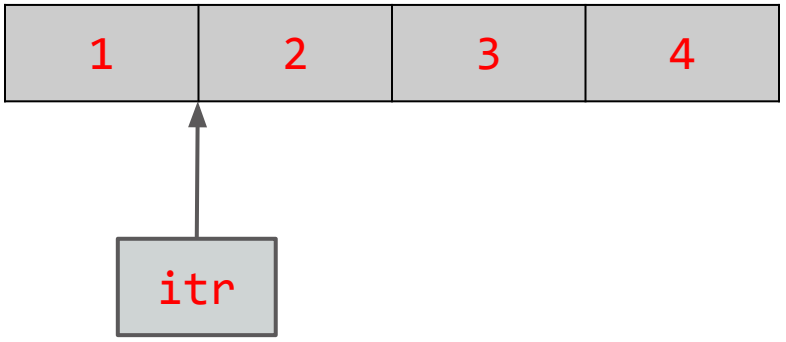
- Let's first try and get a conceptual model of what an iterator is
- We can advance our iterator




```
++itr;
```

Iterators

- Let's first try and get a conceptual model of what an iterator is
- We can keep advancing and dereferencing




```
cout << *itr << endl; //prints 2
```

Iterators

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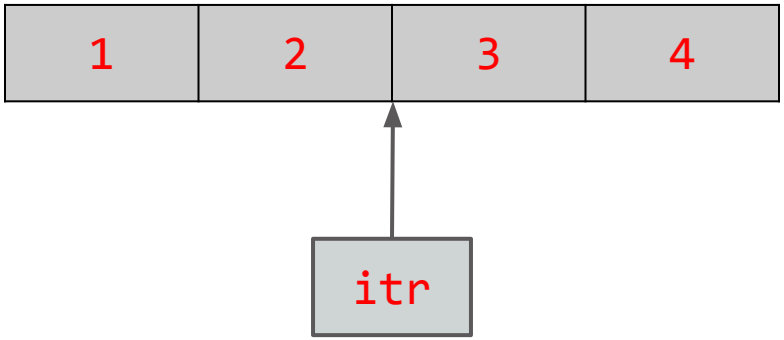
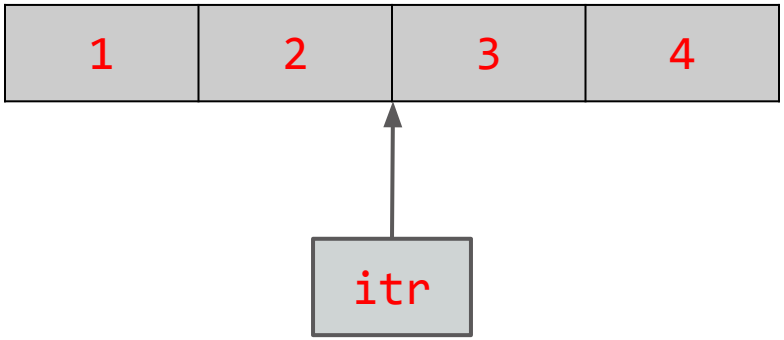
- We can keep advancing and dereferencing




```
++itr;
```

Iterators

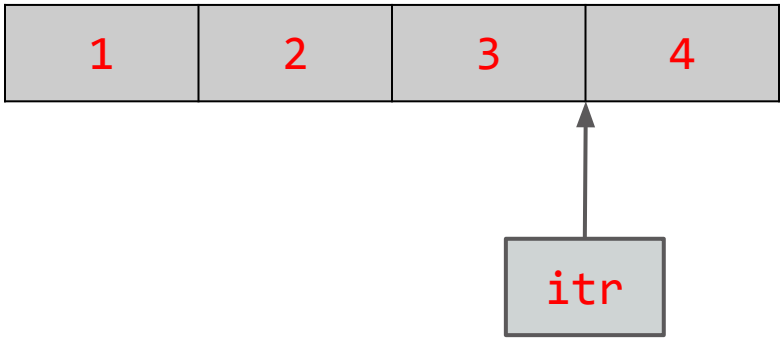
- Let's first try and get a conceptual model of what an iterator is
- We can keep advancing and dereferencing




```
cout << *itr << endl; //prints 3
```

Iterators

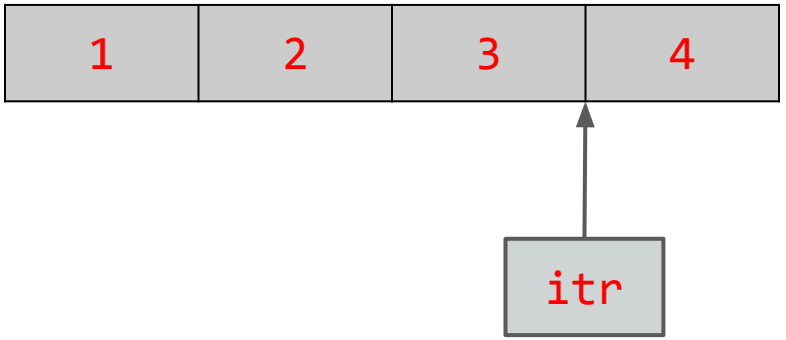
- Let's first try and get a conceptual model of what an iterator is
- We can keep advancing and dereferencing




```
++itr;
```

Iterators

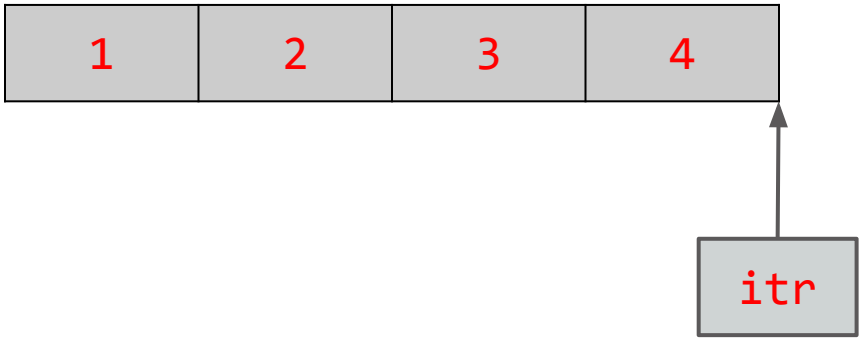
- Let's first try and get a conceptual model of what an iterator is
- We can keep advancing and dereferencing




```
cout << *itr << endl; //prints 4
```

Iterators

- Eventually we reach the end of the container
- We can check if we have reached the end by comparing our iterator to `.end()`




```
if (itr == mySet.end()) return;
```

Iterators

To Recap, four essential iterator operators:

- Create an iterator
- **Dereference** an iterator and read the value it's currently looking at
- **Advance** an iterator
- Compare an iterator against another iterator (especially one from the `.end()` method)

Iterators

Let’s Do Some Examples
(BasicIterator.pro)

Versions of C++

- If we have C++11, why learn about iterators?
  - Not all compilers support C++11
  - Iterators are used for more than just iterating as we will see when we start talking about ranges today and algorithms next week

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Other Uses for Iterators

STL containers often use iterators to specify individual elements inside a container.

```
vector<int> v;
for (int i = 0; i < 10; i++) {
   v.push_back(i);
}
v.erase(v.begin() + 5, v.end());
// v now contains 0, 1, 2, 3, 4
```

Other Uses for Iterators

Iterators don’t always have to iterate through an entire container

```
set<int>::iterator i = mySet.begin();
set<int>::iterator end = mySet.end();
while (i != end) {
   cout << *i << endl;
   ++i;
}
```

Other Uses for Iterators

Here is code that will iterate through all elements **greater than or equal to** 7 and **less than** 26

```
set<int>::iterator i = mySet.lower_bound(7);
set<int>::iterator end = mySet.lower_bound(26);
while (i != end) {
   cout << *i << endl;
   ++i;
}
```

Other Uses for Iterators

Note that we can iterate through various ranges of numbers simply by choosing different values of begin and end

	[a, b]	[a, b)	(a, b]	(a, b)
begin	lower_bound(a)	lower_bound(a)	upper_bound(a)	upper_bound(a)
end	upper_bound(b)	lower_bound(b)	upper_bound(b)	lower_bound(b)

Other Uses for Iterators

Let’s code up some examples

(IteratorRanges.pro)

Iterating through maps

- All of our iterator examples involved set iterators, but (almost) all C++ collections have iterators
- Sequence Container iterators are straightforward
- Maps are a little more complicated

The Pair Class

- A pair is simply two objects bundled together
- Syntax is the following:

```
pair<string, int> p;
p.first = “phone number”;
p.second = 8675309;
```

Iterating through maps

- When iterating through maps, dereferencing returns a pair containing the key and the value of the current element

```
map<int, int> m;
map<int, int>::iterator i = m.begin();
map<int, int>::iterator end = m.end();
while (i != end) {
   cout << (*i).first << (*i).second << endl;
   ++i;
}
```

Multiset

- Sets store unique elements
- If you want to store multiple copies of an element, use a multiset
- Almost all methods are the same

```
multiset<int> myMSet;
myMSet.insert(3);
myMSet.insert(3);
cout << myMSet.count(3) << endl; //prints 2
```

Closing Notes

- Iterators are used everywhere in C++ code
- When you first look at a C++ style iterator, you may find yourself missing foreach, but iterators offer a lot more
- Iterator ranges are just the start. When we start talking about <algorithm> We'll see just how useful iterators can be
- Don't forget assignment one!