Unit 6
Standard Template Library

Contents

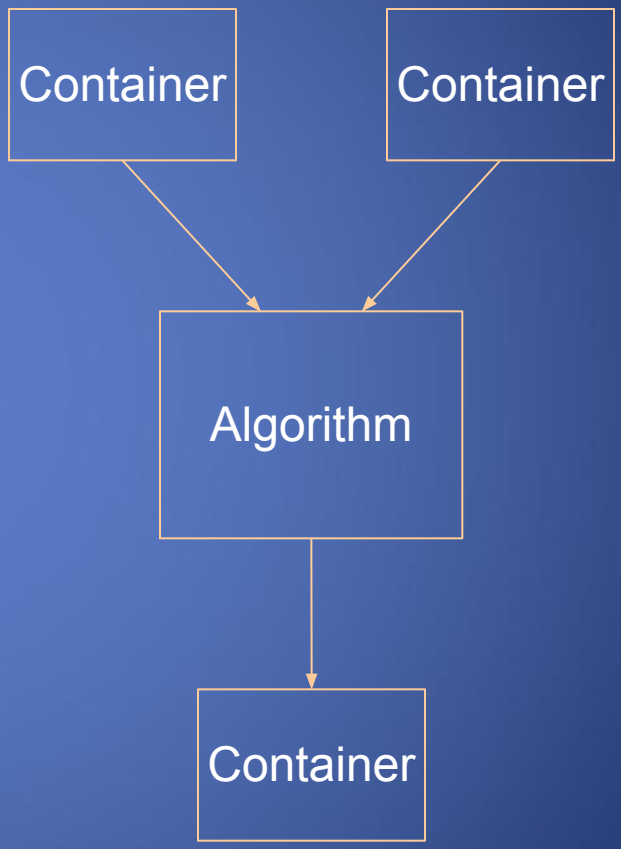
- Introduction To STL
- Containers
- Iterators
- Algorithms

Introduction To STL

- STL is Standard Template Library
  - Powerful, template-based components
    - Containers: template data structures
    - Iterators: like pointers, access elements of containers
    - Algorithms: data manipulation, searching, sorting, etc.
  - Object- oriented programming: reuse, reuse, reuse
  - Only an introduction to STL, a huge class library

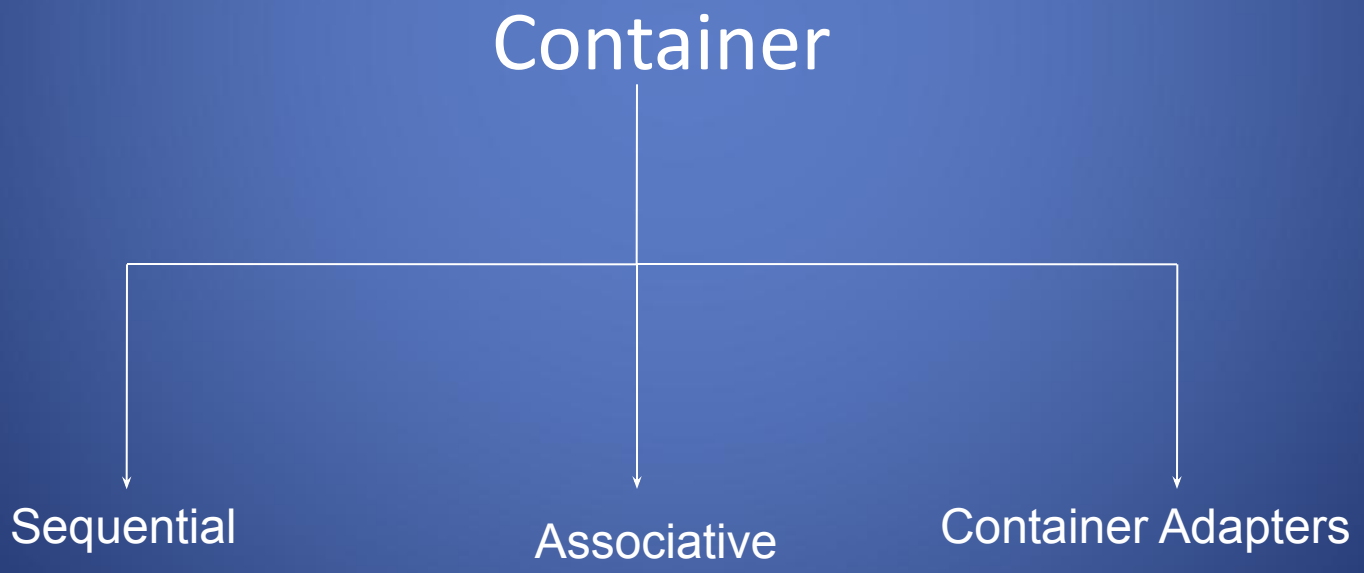
STL components overview

- Data storage, data access and algorithms are separated
  - *Containers* hold data
  - *Iterators* access data
  - *Algorithms*, *function objects* manipulate data
  - *Allocators*... allocate data (mostly, we ignore them)



Container

- A *container* is a way that stored data is organized in memory, for example an array of elements.



Container ctd-

- Sequence containers
  - **`vector`**
  - **`deque`**
  - **`list`**
- Associative containers
  - **`set`**
  - **`multiset`**
  - **`map`**
  - **`multimap`**
- Container adapters
  - **`stack`**
  - **`queue`**

Sequential Container

- `vector<T>` – dynamic array
  - Offers random access, back insertion
  - Should be your ***default choice, but choose wisely***
  - Backward compatible with C : `&v[0]` points to the first element
- `deque<T>` – double-ended queue (usually array of arrays)
  - Offers random access, back and front insertion
  - Slower than vectors, no C compatibility
- `list<T>` – 'traditional' doubly linked list
  - Don't expect random access, you can insert anywhere though

Some functions of vector class

-size()

 -provides the number of elements

-push_back()

 -appends an element to the end

-pop_back()

 -Erases the last element

-begin()

 -Provides reference to last element

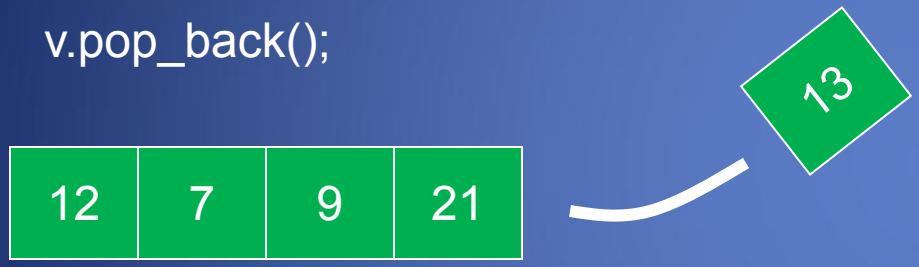
-end()

 -Provides reference to end of vector

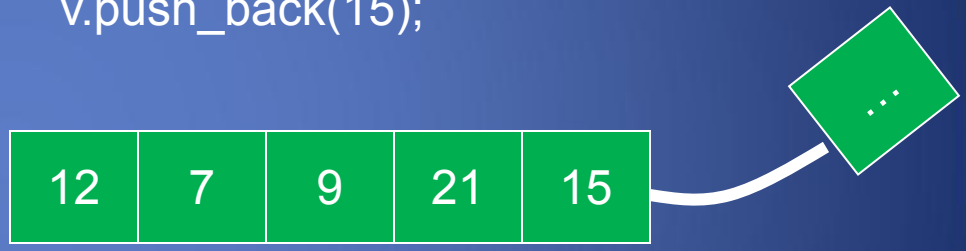
Vector container

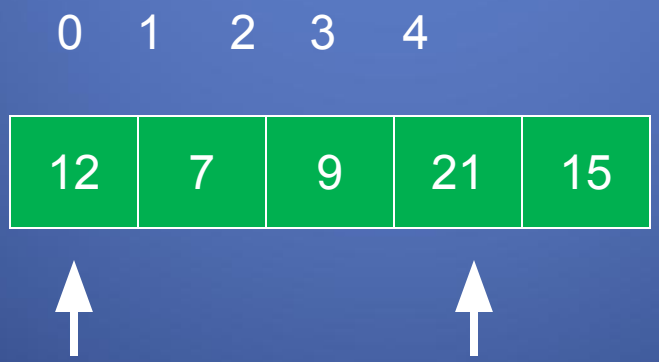
```
int array[5] = {12, 7, 9, 21, 13 };
Vector<int> v(array,array+5);
```

v.pop_back();



v.push_back(15);





Some function of list class

- **list** functions for object **t**
  - **t.sort()**
    - Sorts in ascending order
  - **t.splice(iterator, otherObject);**
    - Inserts values from **otherObject** before **iterator**
  - **t.merge(otherObject)**
    - Removes **otherObject** and inserts it into **t**, sorted
  - **t.unique()**
    - Removes duplicate elements

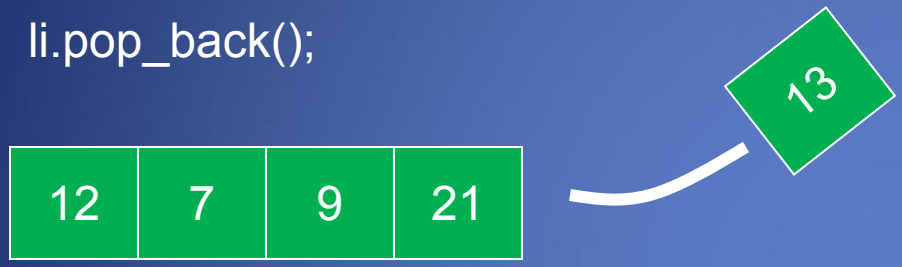
Functions of list class cntd-

- **list** functions
  - **t.swap(otherObject);**
    - Exchange contents
  - **t.assign(iterator1, iterator2)**
    - Replaces contents with elements in range of iterators
  - **t.remove(value)**
    - Erases all instances of **value**

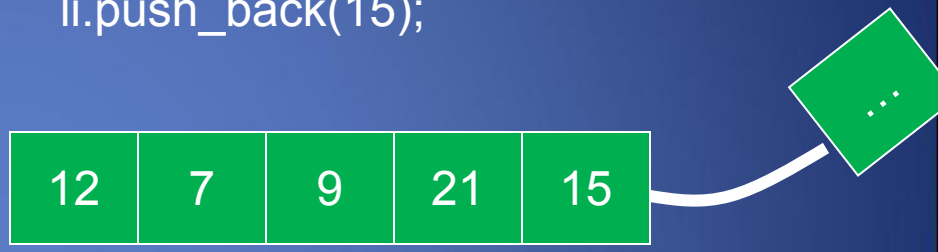
List container

```
int array[5] = {12, 7, 9, 21, 13 };
list<int> li(array,array+5);
```

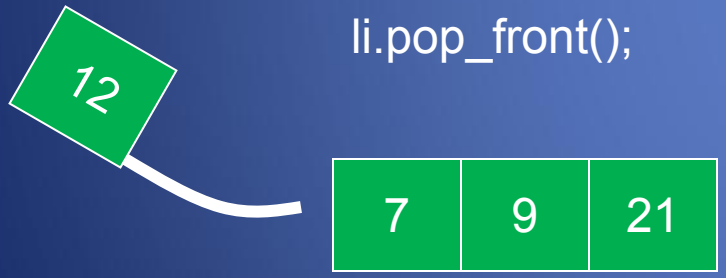
li.pop_back();



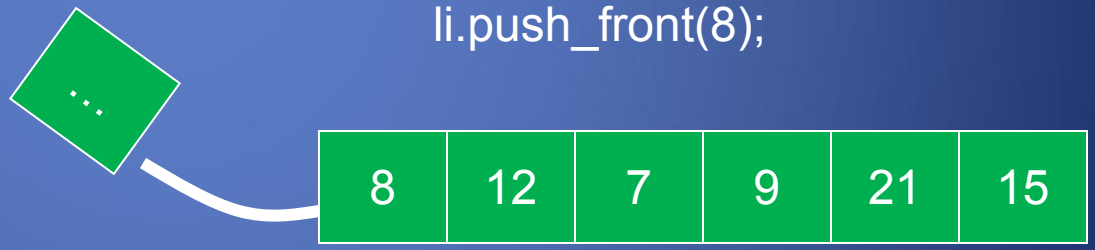
li.push_back(15);



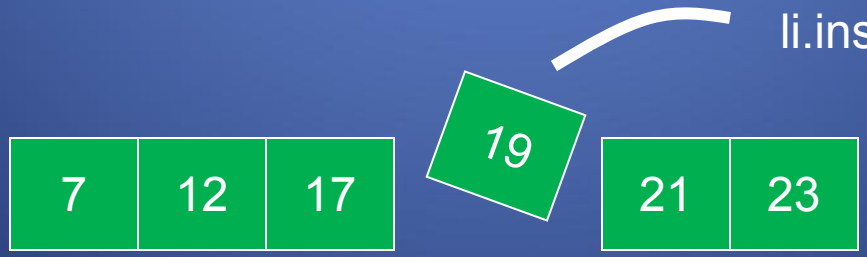
li.pop_front();



li.push_front(8);



li.insert()



Functions of dequeue class

- dequeue functions for object d

  -**d.front()**

  -Return a reference (or const_reference) to the first component of d

  -**d.back()**

  -Return a reference (or const_reference) to the last component of d.

  -**d.size()**

  -Return a value of type size_type giving the number of values currently in d.

Functions of dequeue class contd-

- **d.push_back(val)**
  - Add val to the end of d, increasing the size of d by one.
- **d.push_front(val)**
  - Add val to the front of d, increasing the size of d by one.
- **d.pop_back()**
  - Delete the last value of d. The size of d is reduced by one.
- **d.pop_front()**
  - Delete the first value of d. The size of d is reduced by one.

Associative Containers

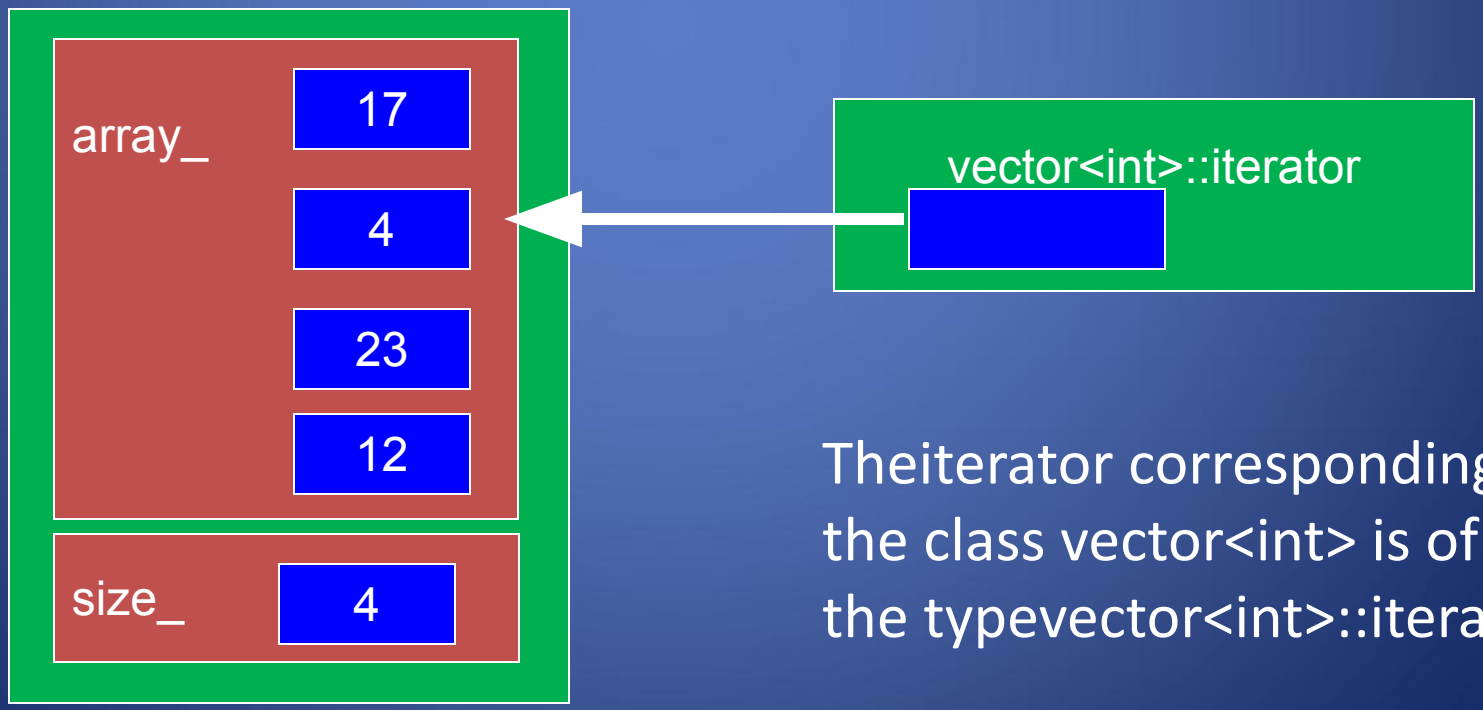
- Offer *O(log n)* insertion, suppression and access
- Store only weakly strict ordered types (eg. numeric types)
  - Must have `operator<()` and `operator==()` defined and !(a<b) && !(b<a) ≡ (a==b)
- The sorting criterion is also a template parameter
- `set<T>` – the item stored act as key, no duplicates
- `multiset<T>` – set allowing duplicate items
- `map<K,V>` – separate key and value, no duplicates
- `multimap<K,V>` – map allowing duplicate keys
- hashed associative containers *may* be available

Container adaptors

- Container adapters
  - **stack**, **queue** and **priority_queue**
  - Not first class containers
    - Do not support iterators
    - Do not provide actual data structure
  - Programmer can select implementation
  - Member functions **push** and **pop**

Iterators

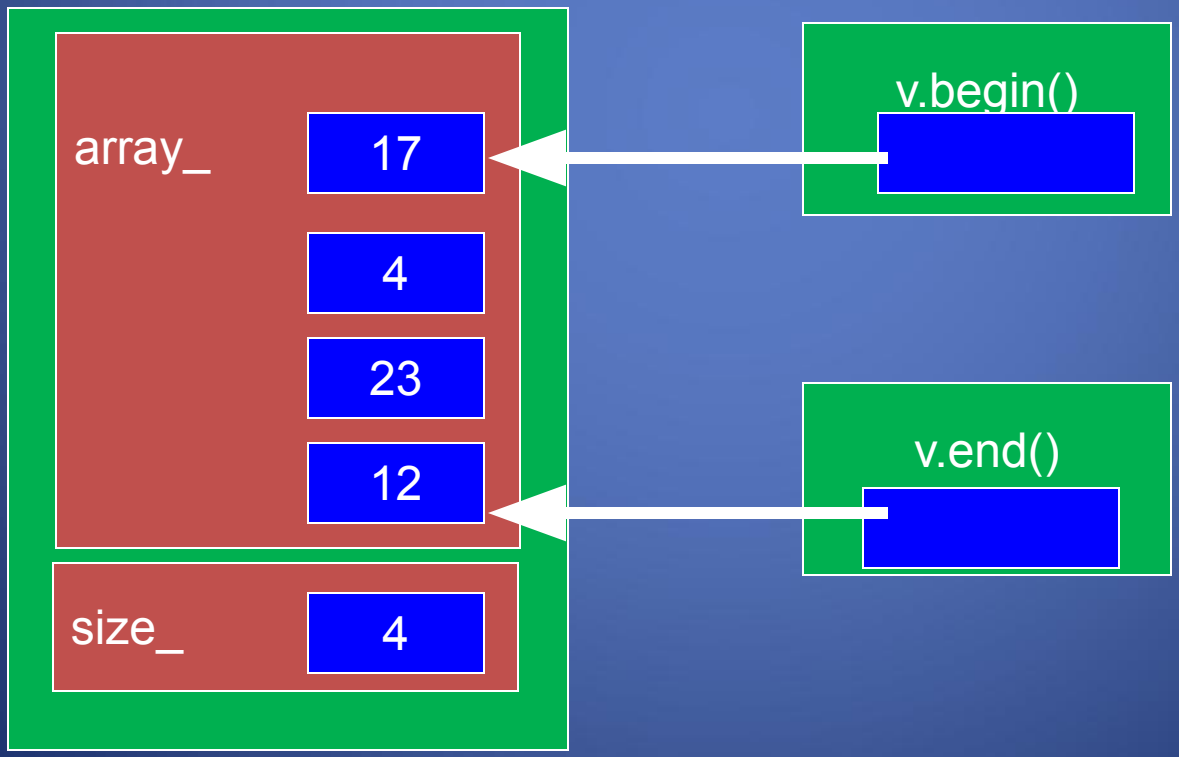
- Iterators are pointer-like entities that are used to access individual elements in a container.
- Often they are used to move sequentially from element to element, a process called *iterating* through a container.



Theiterator corresponding to the class vector<int> is of the typevector<int>::iterator

Iterators contd-

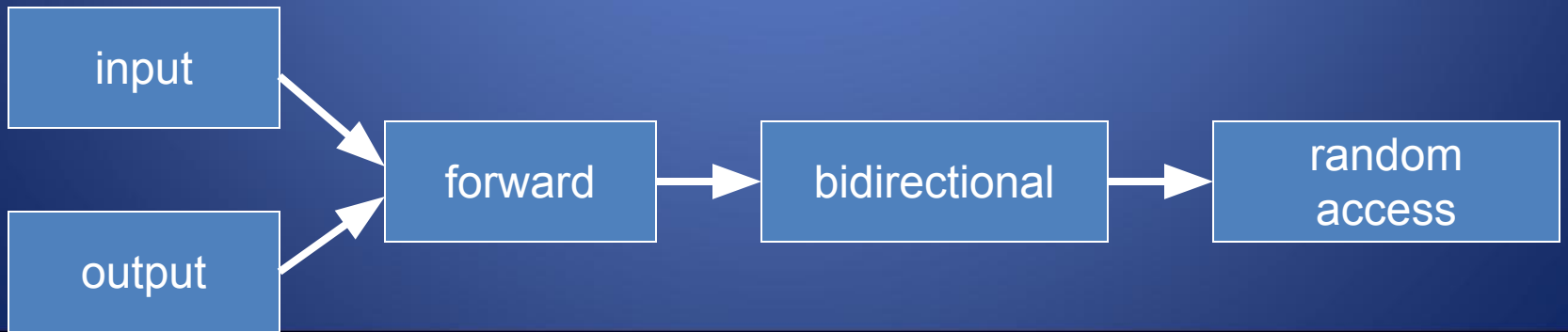
- The member functions begin() and end() return an iterator to the first and past the last element of a container

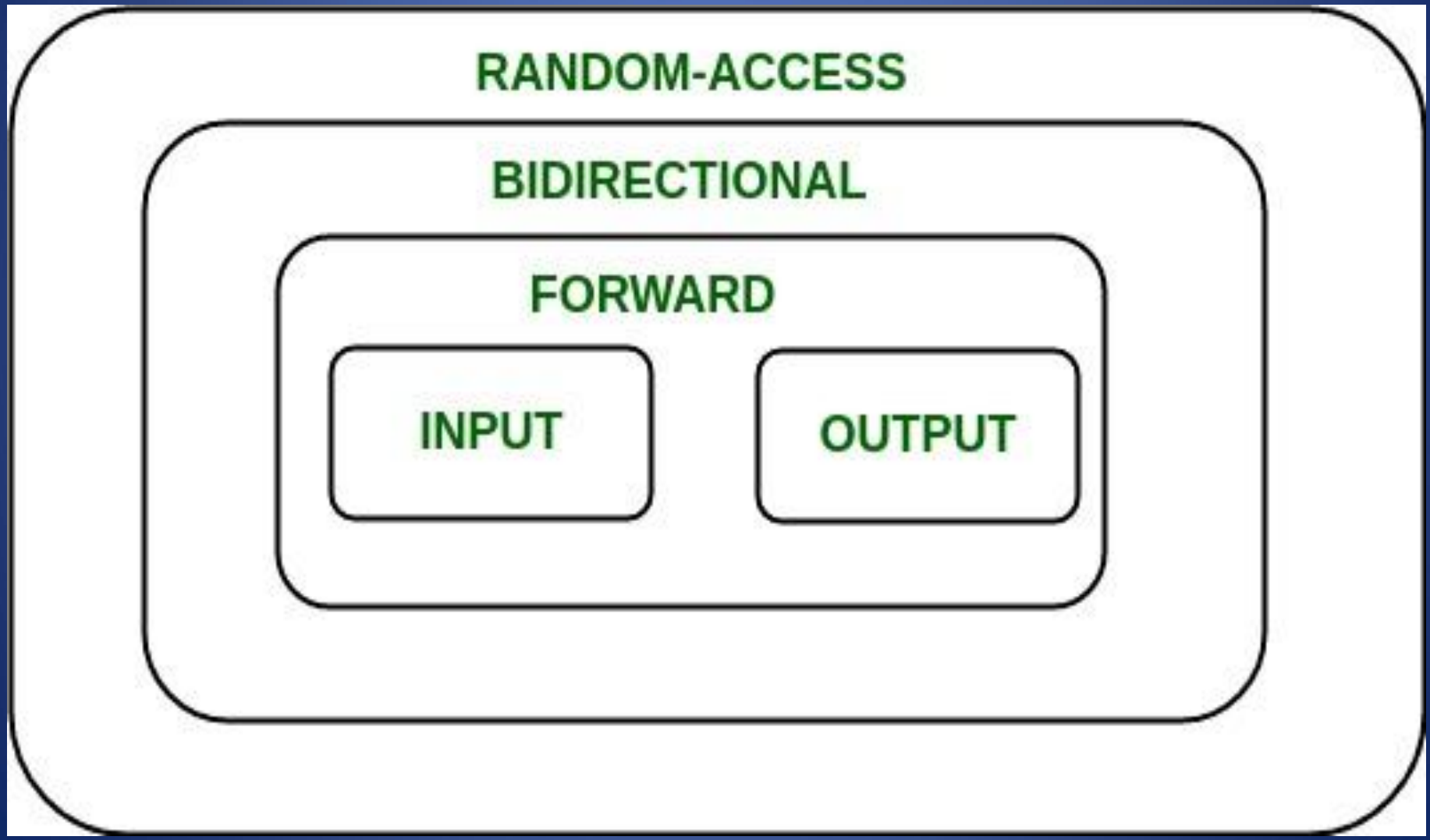


Iterators Categories

- Not every iterator can be used with every container for example the list class provides no random access iterator
- Every algorithm requires an iterator with a certain level of capability for example to use the [] operator you need a random access iterator
- Iterators are divided into five categories in which a higher (more specific) category always subsumes a lower (more general) category, e.g. An algorithm that

  accepts a forward iterator will also work with a bidirectional iterator and a random access iterator




RANDOM-ACCESS
BIDIRECTIONAL
FORWARD
INPUT
OUTPUT

CONTAINER	TYPES OF ITERATOR SUPPORTED
Vector	Random-Access
List	Bidirectional
Deque	Random-Access
Map	Bidirectional
Multimap	Bidirectional
Set	Bidirectional
Multiset	Bidirectional
Stack	No iterator Supported
Queue	No iterator Supported
Priority-Queue	No iterator Supported

Iterators & their Characteristics

Iterator	Access Method	Direction of movement	I/O Capability	Remark
Input	Linear	Forward only	Read only	Cannot be saved
Output	Linear	Forward only	Write only	Cannot be saved
Forward	Linear	Forward only	Read/Write	Can be saved
Bidirectional	Linear	Forward & backward	Read/Write	Can be saved
Random	Random	Forward & backward	Read/Write	Can be saved

Algorithms

Algorithms in the STL are procedures that are applied to containers to process their data, for example search for an element in an array, or sort an array.

Non-Mutating Algorithms

- **sort(first_iterator, last_iterator)** – To sort the given vector.
- **sort(first_iterator, last_iterator, greater<int>())** – To sort the given container/vector in descending order
- **reverse(first_iterator, last_iterator)** – To reverse a vector. (if ascending -> descending OR if descending -> ascending)
- ***max_element (first_iterator, last_iterator)** – To find the maximum element of a vector.

- ***min_element (first_iterator, last_iterator)** – To find the minimum element of a vector.
- **accumulate(first_iterator, last_iterator, initial value of sum)** – Does the summation of vector elements

For_Each() Algorithm

```
#include <vector>
#include <algorithm>
#include <iostream>
void show(int n)
{
  cout << n << ” ”;
}
 int arr[] = { 12, 3, 17, 8 };  // standard C array
vector<int> v(arr, arr+4);  // initialize vector with C array
for_each (v.begin(), v.end(), show); // apply function show
                // to each element of vector v
```

Find() Algorithm

```
#include <vector>
#include <algorithm>
#include <iostream>
int key;
int arr[] = { 12, 3, 17, 8, 34, 56, 9  };  // standard C array
vector<int> v(arr, arr+7);  // initialize vector with C array
vector<int>::iterator iter;
cout << ”enter value :”;
cin >> key;
iter=find(v.begin(),v.end(),key); // finds integer key in v
if (iter != v.end()) // found the element
   cout << ”Element ” << key << ” found” << endl;
else
  cout << ”Element ” << key << ” not in vector v” << endl;
```

Sort & Merge

- Sort and merge allow you to sort and merge elements in a container

```
#include <list>
int arr1[]= { 6, 4, 9, 1, 7 };
int arr2[]= { 4, 2, 1, 3, 8 };
list<int>  l1(arr1, arr1+5); // initialize l1 with arr1
list<int>  l2(arr2, arr2+5); // initialize l2 with arr2
l1.sort();  // l1 = {1, 4, 6, 7, 9}
l2.sort(); // l2= {1, 2, 3, 4, 8 }
l1.merge(l2);  // merges l2 into l1
// l1 = { 1, 1, 2, 3, 4, 4, 6, 7, 8, 9},  l2= {}
```

std::minmax() and std::minmax_element() in C++ STL

- **minmax(a, b):** This function **returns a pair**, in which **1st** element is of **minimum** of the two elements and the **2nd** element is **maximum** of 2 elements.
- **minmax(array of elements):** This function returns similarly as 1st version. Only difference is that in this version, the **accepted argument is a list of integers/strings** among which maximum and minimum are obtained. Useful in cases when we need to find maximum and minimum elements in list without sorting.

```
#include<iostream>
#include<algorithm>
using namespace std;
 int main()
{
   // declaring pair to catch the return value
pair<int, int> mnmx;
 // Using minmax(a, b)
mnmx = minmax(53, 23);
     // printing minimum and maximum values
cout << "The minimum value obtained is : ";
cout << mnmx.first;
cout << "\nThe maximum value obtained is : ";
cout << mnmx.second ;
    // Using minmax((array of elements)
mnmx = minmax({2, 5, 1, 6, 3});
     // printing minimum and maximum values.
cout << "\n\nThe minimum value obtained is : ";
cout << mnmx.first;
cout << "\nThe maximum value obtained is : ";
cout << mnmx.second;
   }
```

Output:

The minimum value obtained is : 23 The maximum value obtained is : 53 The minimum value obtained is : 1 The maximum value obtained is : 6

sort_heap function in C++

- The **sort_heap( )** is an STL algorithm which sorts a heap within the range specified by start and end. Sorts the elements in the heap range [start, end) into ascending order.
- The second form allows you to specify a comparison function that determines when one element is less than another.

Comparing elements using “<":

- Syntax:

template

void sort_heap(RandIter start, RandIter end);

- **start, end :** the range of elements to sort
  Return Value: Since, return type is void, so it does not return any value.

Implementation

```
template
void sort_heap( RandIter start, RandIter end );
{
while (start != end)
 std::pop_heap(start, end--);
 }
```

By comparing using a pre-defined function:

- **Syntax:**

template

void sort_heap(RandIter start, RandIter end, Comp cmpfn);

- **start, end :** the range of elements to sort
- **comp:** comparison function object (i.e. an object that satisfies the requirements of Compare) which returns ?true if the first argument is less than the second.
  Return Value : Since, its return type is void, so it does not return any value.

Implementation

```
template
void sort_heap( RandIter start, RandIter end,
    Comp cmpfn );
{
while (start != end)
std::pop_heap(start, end--, cmpfn);
}
```

Functions Objects

- Some algorithms like sort, merge, accumulate can take a function object as argument.
- A function object is an object of a template class that has a single member function : the overloaded operator ()
- It is also possible to use user-written functions in place of pre-defined function objects

```
#include <list>
#include <functional>
int arr1[]= { 6, 4, 9, 1, 7 };
list<int>  l1(arr1, arr1+5); // initialize l1 with arr1
l1.sort(greater<int>());  // uses function object greater<int>
// for sorting in reverse order l1 = { 9, 7, 6, 4, 1 }
```

Function Objects

- The accumulate algorithm accumulates data over the elements of the containing, for example computing the sum of elements

```
#include <list>
#include <functional>
#include <numeric>
int arr1[]= { 6, 4, 9, 1, 7 };
list<int>  l1(arr1, arr1+5); // initialize l1 with arr1
int sum = accumulate(l1.begin(), l1.end() , 0, plus<int>());
int sum = accumulate(l1.begin(), l1.end(),0);  // equivalent
int fac = accumulate(l1.begin(), l1.end() , 0, times<int>());
```

User Defined Function Objects

```
class squared _sum  // user-defined function object
{
   public:
      int operator()(int n1, int n2) { return n1+n2*n2; }
};
int sq = accumulate(l1.begin(), l1.end() , 0, squared_sum()
    );
// computes the sum of squares
```

Thanks for all the attention ☺️

THANK YOU.!!!

?