11 Generic Programming (*with* STL *in* C++)

Standard Template Library

Nesneye dayalı programlamada, verinin birincil öneme sahip programlama birimi olduğunu belirtmiştik. Veri, fiziksel yada soyut bir çok büyüklüğü modelleyebilir. Bu model oldukça basit yada karmaşık olabilir. Her nasıl olursa olsun, veri mutlaka bellekte saklanmaktadır ve veriye benzer biçimlerde erişilmektedir. C++, oldukça karmaşık veri tiplerini ve yapılarını oluşturmamıza olanak sağlayan mekanizmalara sahiptir. Genel olarak, programların, bu veri yapılarına belirli bazı biçimlerde eriştiğini biliyoruz:

array, list, stack, queue, vector, map, ...

STL kütüphanesi verinin bellekteki organizasyonuna, erişimine ve işlenmesine yönelik çeşitli yöntemler sunmaktadır. Bu bölümde bu yöntemleri inceleyeceğiz.

Standard Template Library (STL) Hewlett Packard'ın Palo Alto (California)'daki laboratuarlarında Alexander Stepanov ve Meng Lee tarafından geliştirilmiştir.

1970'lerin sonlarında Alexander Stepanov bir kısım algoritmaların veri yapısının nasıl depolandıklarından bağımsız olduklarını gözlemledi. Örneğin, sıralama algoritmalarında sıralanacak sayıların bir dizide mi? yoksa bir listede mi? bulunduğunun bir önemi yoktur. Değişen sadece bir sonraki elemana nasıl erişildiği ile ilgilidir. Stepanov bu ve benzeri algoritmaları inceleyerek, algoritmaları veri yapısından bağımsız olarak performanstan ödün vermeksizin soyutlamayı başarmıştır. Bu fikrini 1985'de Generic ADA dilinde gerçekleştirmiştir. Ancak o dönemde henüz C++'da bir önceki bölümde incelediğimiz Template yapısı bulunmadığı için bu fikrini C++'da ancak 1992 yılında gerçekleştirebilmiştir.

Generic Programming

Bir yazılım ürününün bileşenlerini, üç boyutlu uzayda bir nokta olarak düşünebiliriz :

(sıralama,int,array)

(sıralama,double,list)

(sıralama,int,list)

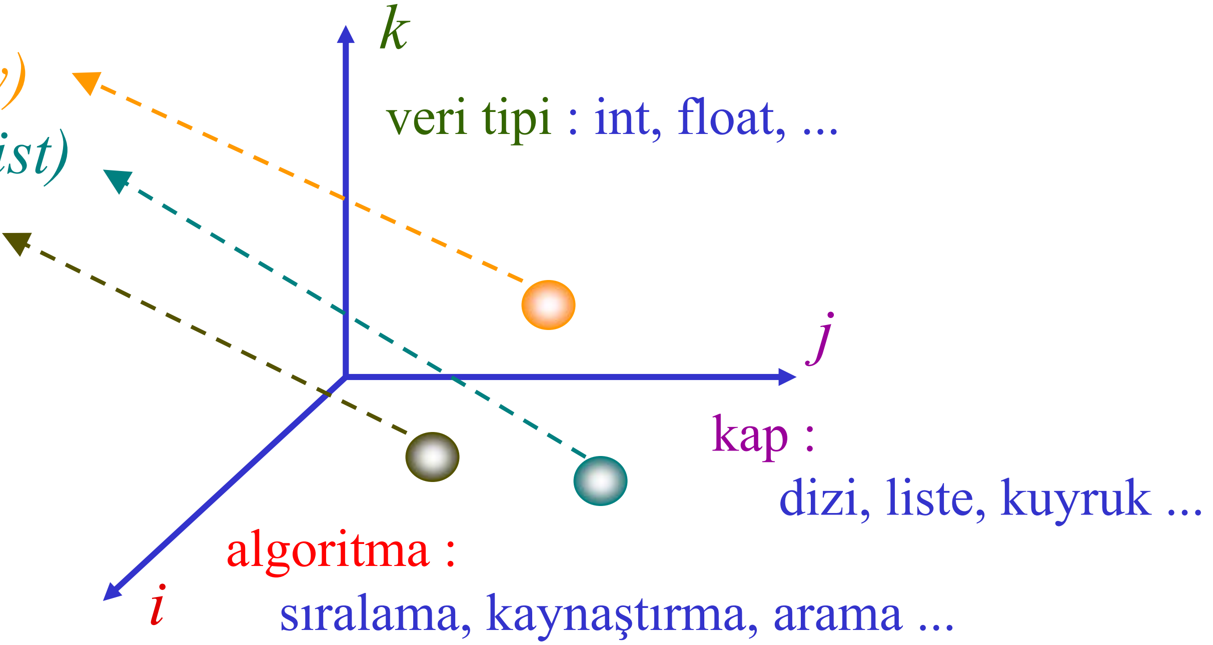
… **template**

(sıralama,array)

(sıralama,list)

… **generic prog.**

(sıralama)



STL Bileşenleri

STL üç temel bileşenden oluşmaktadır:

- **Algoritma**,
- **Kap (Container):** nesneleri depolamak ve yönetmekten sorumlu nesne,
  - Lineer Kaplar : Vector, Deque, List
  - Asosyatif Kaplar : Set, Map, Multi-set, Multi-map
- **Yineleyici (Iterator)**: algoritmanın farklı tipte kaplarla çalışmasını sağlayacak şekilde erişimin soyutlar.

Kaplar

Container	Description	Required Header
bitset	A set of bits	<bitset>
deque	A double-ended queue	<deque>
list	A linear list	<list>
map	Stores key/value pairs in which each key is associated with only one value	<map>
multimap	Stores key/value pairs in which one key may be associated with two or more values	<map>
multiset	A set in which each element is not necessarily unique	<set>
priority_queue	A priority queue	<queue>
queue	A queue	<queue>
set	A set in which each element is unique	<set>
stack	A stack	<stack>
vector	A dynamic array	<vector>

C++’da sabit boyutlu dizi tanımlamak yürütme zamanında belleğin ya kötü kullanılmasına yada dizi boyunun yetersiz kalmasına neden olmaktadır.

STL kütüphanesindeki **vector** kabı bu sorunları gidermektedir.

STL kütüphanesindeki **list** kabı, bağlantılı liste yapısıdır.

deque (D*ouble-Ended QUEue*) kabı, yığın ve kuyruk yapılarının birleşimi olarak düşünülebilir. deque kabı her iki uçtan veri eklemeye ve silmeye olanak sağlamaktadır.

Vector	Relocating, expandable array	Quick random access (by index number). Slow to insert or erase in the middle. Quick to insert or erase at end.
List	Doubly linked list	Quick to insert or delete at any location. Quick access to both ends. Slow random access.
Deque	Like vector, but can be accessed at either end	Quick random access (using index number). Slow to insert or erase in the middle. Quick to insert or erase (push and pop) at either the beginning or the end.

Vector

- #include <vector>
- Kurucular
  - Boş: vector<string> object;
  - Belirli sayıda eleman:
    - vector<string> object(5,string(“hello”)) ;
    - vector<string> container(10)
    - vector<string> object(&container[5], &container[9]);
    - vector<string> object(container) ;

Vector Member Functions

- Type &vector::back(): returns the reference to the last element
- Type &vector::front():returns the reference to the first element
- vector::iterator vector::begin()
- vector::iterator vector::end()
- vector::clear()
- bool vector::empty()
- vector::iterator vector::erase()
  - erase(pos)
  - erase(first,beyond)

Vector Member Functions

- vector::insert
  - vector::iterator insert(pos)
  - vector::iterator insert(pos,value)
  - vector::iterator insert(pos,first,beyond)
  - vector::iterator insert(pos,n,value)
- void vector::pop_back()
- void vector::push_back(value)
- vector::resize()
  - resize(n,value)
- vector::swap()
  - vector<int> v1(7),v2(10) ;
  - v1.swap(v2);
- unsigned vector::size()

Örnek

```
vector<int> v;
cout << v.capacity() << v.size() ;
v.insert(v.end(),3) ;                                   v = (3)
cout << v.capacity() << v.size() ;
v.insert (v.begin(), 2, 5);                             v = (5,5,3)
```

```
vector<int> w (4,9);                                w = (9,9,9,9)
w.insert(w.end(), v.begin(), v.end() );             w = (9,9,9,9,5,5,3)
w.swap(v) ;                v = (9,9,9,9,5,5,3)      w=(5,5,3)
```

```
w.erase(w.begin());                                          w = (5,3)
w.erase(w.begin(),w.end()) ;
cout << w.empty() ? “Empty” : “not Empty”                      Empty
```

11 Generic Programming

```
#define __USE_STL
// STL include files
#include <vector>
#include <list>
```

```
vector<int> v;
v.insert(v.end(),3) ;            v = (3)
v.insert(v.begin(),5) ;          v = (5,3)
cout << v.front() << endl;       5
cout << v.back() ;               3
v.pop_back();
cout << v.back() ;               5
```

11 Generic Programming

List

- #include <list>
- Eklenecek eleman sayısı belirli olmadığı durumlarda uygundur
- Kurucular
  - Boş: list<string> object;
  - Belirli sayıda eleman:
    - list<string> object(5,string(“hello”)) ;
    - list<string> container(10)
    - list<string> object(&container[5], &container[9]);
    - list<string> object(container) ;

List Member Functions

- Type &list::back(): returns the reference to the last element
- Type &list::front():returns the reference to the first element
- list::iterator list::begin()
- list::iterator list::end()
- list::clear()
- bool list::empty()
- list::iterator list::erase()
  - erase(pos)
  - erase(first,beyond)

List Member Functions

- ▶ list::insert
  - list::iterator insert(pos)
  - list::iterator insert(pos,value)
  - list::iterator insert(pos,first,beyond)
  - list::iterator insert(pos,n,value)
- ▶ void list::pop_back()
- ▶ void list::push_back(value)
- ▶ list::resize()
  - resize(n,value)
- ▶ void list<type>::merge(list<type> other)
- ▶ void list<type>::remove(value)
- ▶ unsigned list::size()

list1.cpp

list2.cpp

List Member Functions

- ▶ list::sort()
- ▶ void list::splice(pos,object)

list3.cpp

- ▶ void list::unique(): operates on sorted list, removes consecutive identical elements

list4.cpp

Queue

- ▶ #include <queue>
- ▶ FIFO (=First In First Out)
- ▶ Kurucular
  - – Boş: queue<string> object;
  - – Kopya Kurucu: queue<string> object(container) ;

Queue Member Functions

- Type &queue::back(): returns the reference to the last element
- Type &queue::front(): returns the reference to the first element
- bool queue::empty()
- void queue::push(value)
- void queue::pop()

Priority_Queue

- ►#include <queue>
- ►Temel olarak queue ile aynı
- ►Kuyruğa ekleme belirli bir önceliğe göre yürütülür
- ►Öncelik: operator<()

priqueue1.cpp

priqueue2.cpp

Priority_Queue Member Functions

- Type &queu::back(): returns the reference to the last element
- Type &queue::front():returns the reference to the first element
- bool queue::empty()
- void queue::push(value)
- void queue::pop()

Deque

- #include <deque>
- Head &Tail, Doubly Linked
- deque<string> object
  - deque<string> object(5,string(“hello”)) ;
  - deque<string> container(10)
  - deque<string> object(&container[5], &container[9]);
  - deque<string> object(container) ;

Deque Member Functions

- Type &deque::back(): returns the reference to the last element
- Type &deque::front():returns the reference to the first element
- deque::iterator deque::begin()
- deque::iterator deque::end()
- deque::clear()
- bool deque::empty()
- deque::iterator deque::erase()
  - erase(pos)
  - erase(first,beyond)

Deque Member Functions

- vector::insert
  - deque::iterator insert(pos)
  - deque::iterator insert(pos,value)
  - deque::iterator insert(pos,first,beyond)
  - deque::iterator insert(pos,n,value)
- void deque::pop_back()
- void deque::push_back(value)
- deque::resize()
  - resize(n,value)
- deque::swap()
- unsigned deque::size()

Asosyatif Kaplar: Set, Multiset, Map, Multimap

- Set sıralı küme oluşturmak için kullanılır.

```
#include <set>
using namespace std;
int main(){
   string names[] = {"Katie", "Robert","Mary", "Amanda", "Marie"};
   set<string> nameSet(names, names+5);// initialize set to array
   set<string>::const_iterator iter;  // iterator to set
   nameSet.insert("Jack");           // insert some more names
   nameSet.insert("Larry");
   nameSet.insert("Robert");          // no effect; already in set
   nameSet.insert("Barry");
   nameSet.erase("Mary");             // erase a name
```

```
    cout << "\nSize=" << nameSet.size() << endl;
    iter = nameSet.begin();             // display members of set
    while( iter != nameSet.end() )
       cout << *iter++ << '\n';
    string searchName;                  // get name from user
    cout << "\nEnter name to search for: ";
    cin >> searchName;      // find matching name in set
    iter = nameSet.find(searchName);
    if( iter == nameSet.end() )
       cout << "The name" << searchName << " is NOT in the set.";
    else
       cout << "The name " << *iter << " IS in the set.";
}
```

```
// set2.cpp set
int main() {
   set<string> city;
   set<string>::iterator iter;
   city.insert("Trabzon");     // insert city names
   city.insert("Adana");
   city.insert("Edirne");
   city.insert("Bursa");
   city.insert(“Istanbul");
   city.insert("Rize");
   city.insert("Antalya");
   city.insert(“Izmir");
   city.insert("Hatay");
   city.insert("Ankara");
   city.insert("Zonguldak");
iter = city.begin();            // display set
  while( iter != city.end() )
    cout << *iter++ << endl;

  string lower, upper;           // display entries in range
  cout << "\nEnter range (example A Azz): ";
  cin >> lower >> upper;
  iter = city.lower_bound(lower);
  while( iter != city.upper_bound(upper) )
    cout << *iter++ << endl;
}
```

11 Generic Programming

Map

- #include <map>
- Key/Value pairs
- map<string,int> object
  - pair<string,int>

    ```
    pa[]= {
            pair<string,int>(“one”,1),
            pair<string,int>(“two”,2),
            pair<string,int>(“three”,3),
            pair<string,int>(“four”,4)
        } ;
    ```
  - map<string,int> object(&pa[0],&pa[3]);
- object[“two”]

Map Member Functions

- ▶ map::insert
  - pair<map::iterator,bool> insert(keyvalue)
  - pair<map::iterator,bool> insert(pos,keyvalue)
  - void insert(first,beyond)
- ▶ map::iterator map::lower_bound(key)
- ▶ map::iterator map::upper_bound(key)
- ▶ pair<map::iterator,map::iterator> map::equal_range(key)
- ▶ map::iterator map::find(key)
  - returns map::end() if not found
- ▶ unsigned deque::size()

Map Member Functions

- map::iterator map::begin()
- map::iterator map::end()
- map::clear()
- bool map::empty()
- map::iterator map::erase()
  - erase(keyvalue)
  - erase(pos)
  - erase(first,beyond)

Örnek

```
int main(){
  map<string,int> city_num;
  city_num["Trabzon"]=61;
   ...
  string city_name;
  cout << "\nEnter a city: ";
  cin >> city_name;
  if (city_num.end()== city_num.find(city_name))
    cout << city_name << " is not in the database" << endl;
  else
    cout << "Number of " << city_name << ": " << city_num[city_name];
}
```

MultiMap

- #include <map>
- Main difference between map and multimap is that the multimap supports multiple entries of values having the same keys and the same values.

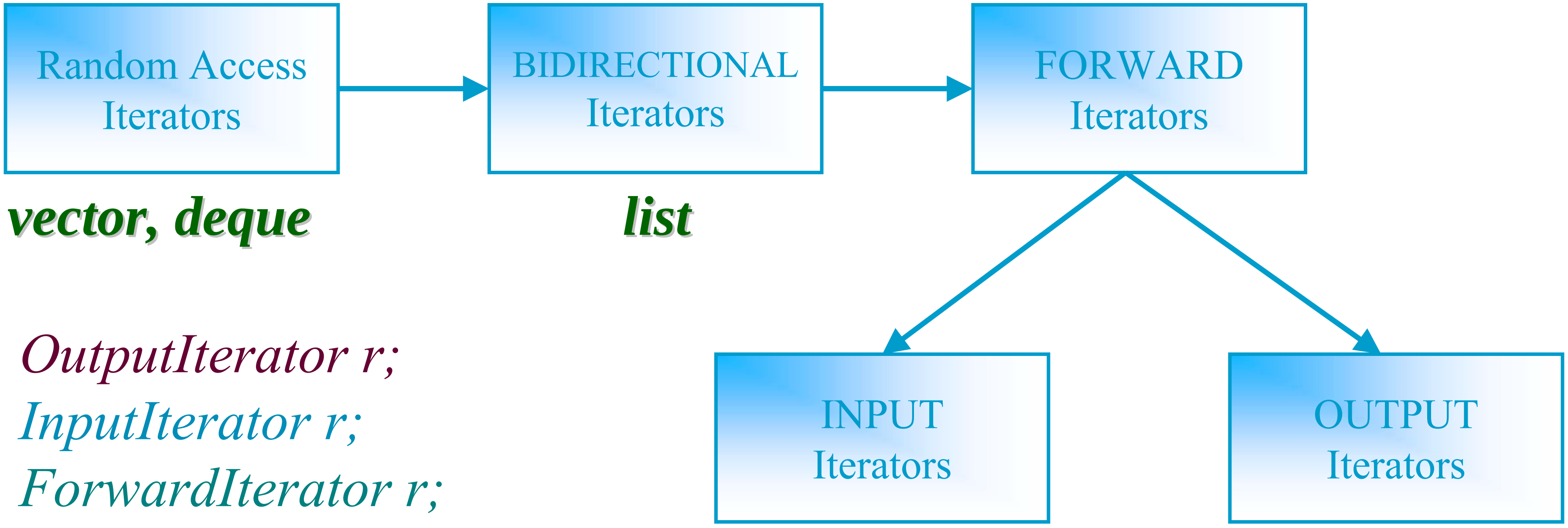
Özetçe

İşlem	Yürütülen İşlem
a.size()	a.end() – a.begin()
a.max_size()	
a.empty()	a.size() == 0

İşlem	Dönüş Değeri	Yürütülen İşlem	Uygulanabildiği Kaplar
a.front()	T&	*a.begin()	vector, list, deque
a.back()	T&	*a.end()	vector, list, deque
a.push_front(x)	void	a.insert(a.begin(),x)	list,deque
a.push_back(x)	void	a.insert(a.end(),x)	vector, list,deque
a.pop_front()	void	a.erase(a.begin())	list,deque
a.pop_back()	void	a.erase(--a.end())	list,deque
a[n]	T&	*(a.begin()+n)	vector,deque

Iterators

Iterators : Genelleştirilmiş İşaretçi



vector, deque

list

OutputIterator r;
InputIterator r;
ForwardIterator r;
BidirectionalIterator r;
RandomIterator r ;

Iterator Capability

Iterator Capability	Input	Output	Forward	Bidirectional	Random Access
Dereferencing read	yes	no	yes	yes	yes
Dereferencing write	no	yes	yes	yes	yes
Fixed and repeatable order	no	no	yes	yes	yes
++i i++	yes	yes	yes	yes	yes
--i i--	no	no	no	yes	yes
i[n]	no	no	no	no	yes
i + n	no	no	no	no	yes
i - n	no	no	no	no	yes
i += n	no	no	no	no	yes
i -=n	no	no	no	no	yes

Output Iterators

❶

```
OutputIterator a ;
...
*a=t ;
t = *a ;            Hata
```

❸

```
OutputIterator r ;
...
r++ ;
r++ ;               Hata
```

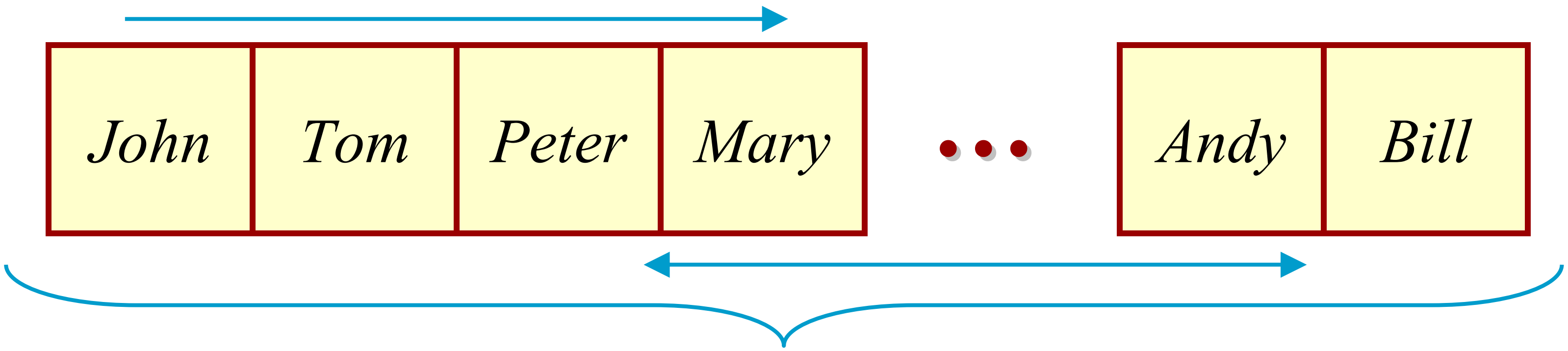
❷

```
OutputIterator r ;
...
*r=0 ;
*r=1 ;              Hata
```

❹

```
OutputIterator i,j ;
...
i=j ;
*i++=a ;            Hata
*j=b ;
```

Forward and Bidirectional Iterators



range[v.begin(),v.end()]

```
list<int> l (1,1) ;
l.push_back(2) ; // list l : 1 2
list<int>::iterator first=l.begin() ;
list<int>::iterator last=l.end() ;
while( last != first){
      -- last ;
      cout << *last << “ ” ;
}
```

```
template<class ForwardIterator, class T>
ForwardIterator find_linear(ForwardIterator first,
                             ForwardIterator last, T& value){
        while( first != last) if( *first++ == value) return first;
                                    else return last ;
}

vector<int> v(3,1) ;
v.push_back(7);  // vector : 1 1 1 7
vector<int>::iterator i=find_linear(v.begin(), v.end(),7) ;
if(i != v.end() ) cout << *i ;
else cout << “not found!” ;
```

Bubble Sort

```
template<class Compare>
void bubble_sort(BidirectionalIterator first,
                      BidirectionalIterator last, Compare comp){
 BidirectionalIterator left = first , right = first ;
 right ++ ;
   while( first != last){
       while( right != last ){
              if( comp(*right,*left) )
                 iter_swap(left,right) ;
              right++ ;
              left++;
       }
       last -- ;
       left = first ; right = first ;
   }
}
```

```
list<int> l ;
bubble_sort(l.begin(),l.end(),less<int>()) ;
bubble_sort(l.begin(),l.end(),greater<int>()) ;
```

Random Access Iterators

```
vector<int> v(1,1) ;
v.push_back(2) ; v.push_back(3) ; v.push_back(4) ; // v : 1 2 3 4
vector<int>::iterator i=v.begin() ;
vector<int>::iterator j=i+2;
cout << *j << “ ” ;
i += 3 ; cout << *i << “” ;
j = i – 1 ; cout << *j << “” ;
j -= 2 ; cout << *j << “” ;
cout << v[1] << endl ;
(j<i) ? cout << “j < i” : cout << “not j < i” ; cout << endl ;
(j>i) ? cout << “j > i” : cout << “not j > i” ; cout << endl ;
(j>=i) && (j<=i)? cout << “j and i equal” : cout << “j and i not equal > i” ; cout <<
endl ;
i = j ;
j= v.begin();
i = v.end ;
cout << “iterator distance end – begin : ” << (i-j) ;
```

Iterator Operators

- STL provides two functions that return the number of elements between two elements and that jump from one element to any other element in the container:
  - distance()
  - advance()

distance()

- The distance() function finds the distance between the current position of two iterators.

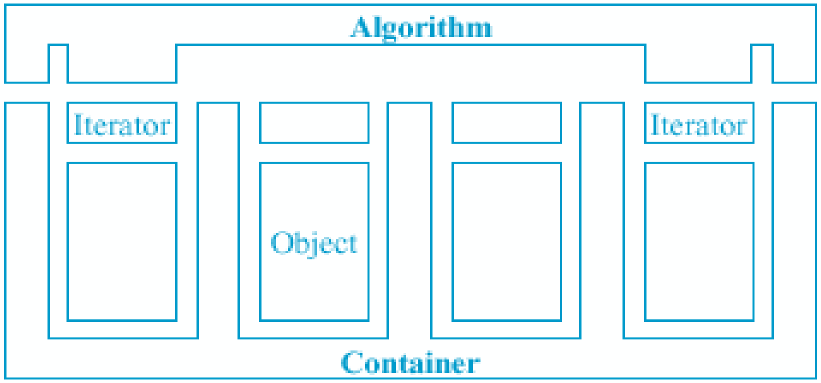
```
template<class RandomAccessIterator>
iterator_traits<RandomAccessIterator>::difference_type
distance(RandomAccessIterator first, RandomAccessIterator
   last) {
       return last – first;
}
template<class InputIterator>
iterator_traits<InputIterator>::difference_type
distance(InputIterator first, InputIterator last) {
iterator_traits<InputIterator>::difference_type n = 0;
       while (first++ != last) ++n;
        return n;
}
```

advance()

- So far, we have seen how we can move iterators forward and backward by using the increment and decrement operators, respectively. We can also move random access iterators several steps at a time using the addition and subtraction functions. Other types of iterators, however, do not have the addition and subtraction functions.
- The STL provides the advance() function to move any iterator—except the output iterators—several steps at a time:

```
template<class InputIterator, class Distance>
void advance(InputIterator& ii, Distance& n) {
        while (n--) ++ii;
}
template<class BidirectionalIterator, class Distance>
void advance(BidirectionalIterator & bi, Distance& n) {
        if (n >= 0) while (n--) ++bi;
       else while (n++) --bi;
}
template<class RandomAccessIterator, class Distance>
void advance(RandomAccessIterator& ri, Distance& n) {
        ri += n;
}
```

Designing Generic Algorithm



implementing an algorithm such as computing the maximum value in a sequence can be done without knowing the details of how values are stored in that sequence:

```
template <class Iterator>
Iterator max_element (Iterator beg,   // refers to start of collection
                      Iterator end)   // refers to end of collection
{
   …
}
```

Binary Search for Integer Array

```
const int * binary_search(const int * array, int n, int x){
    const int *lo = array, *hi = array + n , *mid ;
    while( lo != hi ) {
        mid = lo + (hi-lo)/2 ;
        if( x == *mid ) return mid ;
        if( x < *mid ) hi = mid ;
        else lo = mid + 1 ;
    }
  return 0 ;
}
```

Binary Search—Template Solution (Form-1)

```
template<class T>
const T * binary_search(const T * array, int n, T& x){
    const T *lo = array, *hi = array + n , *mid ;
    while( lo != hi ) {
            mid = lo + (hi-lo)/2 ;
            if( x == *mid ) return mid ;
            if( x < *mid ) hi = mid ;
            else lo = mid + 1 ;
    }
  return 0 ;
}
```

Binary Search—Template Solution (Form-2)

11 Generic Programming

```
template<class T>
const T * binary_search(T * first,T * last, T& x){
     const T *lo = first, *hi = last , *mid ;
     while( lo != hi ) {
              mid = lo + (hi-lo)/2 ;
              if( x == *mid ) return mid ;
              if( x < *mid ) hi = mid ;
              else lo = mid + 1 ;
     }
  return last ;
}
```

Generic Binary Search

```
template<class RandomAccessIterator,class T>
const T * binary_search(RandomAccessIterator first,
                                    RandomAccessIterator last, T& value){
 RandomAccessIterator not_found = last, mid ;
 RandomAccessIterator lo= first, hi=last ;
     while( lo != hi ) {
              mid = lo + (hi-lo)/2 ;
              if( value == *mid ) return mid ;
              if( value < *mid ) hi = mid ;
              else lo = mid + 1 ;
     }
  return not_found ;
}
```

STL Algorithms

#include <algorithm>

Algorithm	Purpose
find	Returns first element equivalent to a specified value
count	Counts the number of elements that have a specified value
equal	Compares the contents of two containers and returns true if all corresponding elements are equal
search	Looks for a sequence of values in one container that correspond with the same sequence in another container
copy	Copies a sequence of values from one container to another (or to a different location in the same container)
swap	Exchanges a value in one location with a value in another
iter_swap	Exchanges a sequence of values in one location with a sequence of values in another location
fill	Copies a value into a sequence of locations
sort	Sorts the values in a container according to a specified ordering
merge	Combines two sorted ranges of elements to make a larger sorted range
accumulate	Returns the sum of the elements in a given range
for_each	Executes a specified function for each element in the container

find()

- The find() algorithm looks for the first element in a container that has a specified value.
- find() example program shows how this looks when we're trying to find a value in an array of int's.

Example

```
#include <iostream>
#include <algorithm>                    //for find()
int arr[] = { 11, 22, 33, 44, 55, 66, 77, 88 };
int main() {
   int* ptr;
   ptr = find(arr, arr+8, 33);          //find first 33
   cout << “First object with value 33 found at offset ”
            << (ptr-arr) << endl;
   return 0;
}
```

count()

- count() counts how many elements in a container have a specified value and returns this number.

```
#include <iostream>
#include <algorithm>        //for count()
int arr[] = { 33, 22, 33, 44, 33, 55, 66, 77 };

int main(){
    int n = count(arr, arr+8, 33);  //count number of 33’s
    cout << “There are “ << n << ” 33’s in arr.” << endl;
    return 0;
}
```

count_if()

- size_t count_if(InputIterator first, InputIterator last, Predicate predicate)

```
#include <vector>
#include <algorithm>  //for count_if()
int a[] = { 1, 2, 3, 4, 3, 4, 2, 1, 3 };
class Odd {
    public:
        bool operator()(int val){ return val&1 ; }
};
int main(){
    std::vector<int> iv(a,a+9) ;
    std::cout << count_if(iv.begin(),iv.end(),Odd()) ;
    return 0 ;
}
```

equal()

- bool equal(InputIterator first, InputIterator last,
  InputIterator otherFirst)
- bool equal(InputIterator first, InputIterator last,
  InputIterator otherFirst,Predicate predicate)

```
class CaseString {
    public:
        bool operator()(string const &first,string const &second){
            return !strcasecmp(first.c_str(),second.c_str()) ;
        }
};
int main(){
    string
   first[]={"Alpha","bravo","Charley","echo","Delta","golf"},
   second[]={"alpha","Bravo","charley","Echo","delta","Golf"} ;
    std::string *last = first + sizeof(first)/sizeof(std::string) ;
    cout << (equal(first,last,second)?"Equal":"Not equal") ;
    cout << (equal(first,last,second,CaseString())?"Equal":
                                                        "Not equal") ;
    return 0 ;
}
```

fill(),fill_n()

- ▶void fill(ForwardIterator first,ForwardIterator last,
  Type const &value)

```
vector<int> iv(8) ;
fill(iv.begin(),iv.end(),8) ;
```

- ▶void fill_n(ForwardIterator first,Size n,
  Type const &value)

```
vector<int> iv(8) ;
fill_n(iv.begin()+2,4,8) ;
```

sort()

- You can guess what the sort() algorithm does.

  Here’s an example:

```
#include <iostream>
#include <algorithm>
int arr[] = {45, 2, 22, -17, 0, -30, 25, 55};
int main(){
   sort(arr, arr+8);              //sort the numbers
   for(int j=0; j<8; j++)      //display sorted array
      cout << arr[j] << ‘ ‘;
   return 0;
}
```

search()

- Some algorithms operate on two containers at once. For instance, while the find() algorithm looks for a specified value in a single container, the search() algorithm looks for a sequence of values, specified by one container, within another container.

```
int source[] =  { 11, 44, 33, 11, 22, 33, 11, 22, 44 };
int pattern[] = { 11, 22, 33 };
int main(){
 int* ptr;
 ptr = search(source, source+9, pattern, pattern+3);
 if(ptr == source+9)   cout << “No match found\n”;
 else                  cout << “Match at ” << (ptr - source) ;
   return 0;
}
```

binary_search()

- #include <algorithm>
  - bool binary_search(ForwardIterator first, ForwardIterator last,Type const &value)
  - bool binary_search(ForwardIterator first, ForwardIterator last,Type const &value,Comparator comp)

merge()

```
#include <iostream>
#include <algorithm>          //for merge()
using namespace std;
int src1[] = { 2, 3, 4, 6, 8 };
int src2[] = { 1, 3, 5 };
int dest[8];
int main(){              //merge src1 and src2 into dest
    merge(src1, src1+5, src2, src2+3, dest);
    for (int j=0; j<8; j++)      //display dest
        cout << dest[j] << ‘ ‘;
    cout << endl;
    return 0;
}
```

accumulate()

- #include <numeric>
  - Type accumulate(InputIterator first, InputIterator last,Type init)

    operator+() is applied to all elements and the result is returned
  - Type accumulate(InputIterator first, InputIterator last,
    Type
    init,BinaryOperation op)

    binary operator op() is applied to all elements

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

int main(){
    int ia[]={1,2,3,4} ;
    std::vector<int> iv(ia,ia+4) ;

    cout << accumulate(iv.begin(),iv.end(),int()) << std::endl ;
    cout << accumulate(iv.begin(),iv.end(),int(1),multiplies<int>())
            << endl ;
    system("pause") ;
    return 0 ;
}
```

adjacent_difference()

▶ #include <numeric>

- OutputIterator adjacent_difference(InputIterator first, InputIterator last,OutputOperator result)
- OutputIterator adjacent_difference(InputIterator first, InputIterator last,
  OutputOperator result,BinaryOperation op)

```
#include <iostream>
#include <numeric>
#include <vector>
int main(){
    int ia[]={1,3,7,23} ;
    std::vector<int> iv(ia,ia+4) ;
    std::vector<int> ov(iv.size()) ;
    adjacent_difference(iv.begin(),iv.end(),ov.begin()) ;
    copy(ov.begin(),ov.end(),std::ostream_iterator<int>(cout," ")) ;
    std::cout << std::endl ;

   adjacent_difference(iv.begin(),iv.end(),ov.begin(),minus<int>()) ;
    copy(ov.begin(),ov.end(),ostream_iterator<int>(cout," ")) ;
    system("pause") ;
    return 0 ;
}
```

copy(), copy_backward()

- #include <algorithm>
  - OutputIterator copy(InputIterator first, InputIterator last,
    OutputIterator destination)
  - BidirectionalIterator copy(InputIterator first, InputIterator last, BidirectionalIterator last2)

for_each

- Function for_each(ForwardIterator first,
  ForwardIterator last,Function func)

```
void lowerCase(char &c){
    c = static_cast<char>(tolower(c)) ;
}
void capitalizedOutput(std::string const &str){
    char *tmp = strcpy(new char[str.size()+1],str.c_str()) ;
    std::for_each(tmp+1,tmp+str.size(),lowerCase) ;

    tmp[0] = toupper(*tmp) ;
    std::cout << tmp << " " ;
    delete []tmp;
}
```

foreach1.cpp

```
int main(){
    std::string
        sarr[] =
        {
           "alpha", "BRAVO", "charley", "ECHO", "delta",
           "FOXTROT", "golf", "HOTEL"
        },
        *last = sarr + sizeof(sarr) / sizeof(std::string) ;
    void (*f)(std::string const&) ;
    f = std::for_each(sarr,last,capitalizedOutput) ;
    std::cout << std::endl ;
    f("alpha") ;
    std::cout << std::endl ;
    system("pause") ;
    return 0 ;
}
```

Another Example

```
class Show{
      int d_count ;
   public:
      void operator()(std::string &str){
          for_each(str.begin(),str.end(),lowerCase) ;
          str[0] =toupper(str[0]);
          std::cout << ++d_count << " " << str << "; " ;
      }
      int getCount() const{
         return d_count ;
      }
} ;
```

foreach2.cpp

```
int main(){
    std::string
        sarr[] =  {
                        "alpha", "BRAVO", "charley", "ECHO", "delta",
                        "FOXTROT", "golf", "HOTEL"
                     },
                     *last = sarr + sizeof(sarr) / sizeof(std::string) ;
    cout << for_each(sarr,last,Show()).getCount() << endl ;
    system("pause") ;
    return 0 ;
}
```

transform()

```
int _3_n_plus_1(int n) {
    return (n&1) ? 3*n+1 : n/2 ;
}
```

```
void show(int n) {
      std::cout << n << " " ;
 }
```

```
int main(){
   int iArr[] = { 5,2,23,76,33,44} ;
   std::for_each(iArr,iArr+6,show) ; std::cout << std::endl ;
   std::transform(iArr,iArr+6,iArr,_3_n_plus_1) ;
   std::for_each(iArr,iArr+6,show) ;
   system("pause") ;
   return 0 ;
}
```

transform.cpp

Predicates in <functional>

- When the type of the return value of a unary function object is bool, the function is called a unary predicate. A binary function object that returns a bool value is called a binary predicate.
- The Standard C++ Library defines several common predicates in <functional>

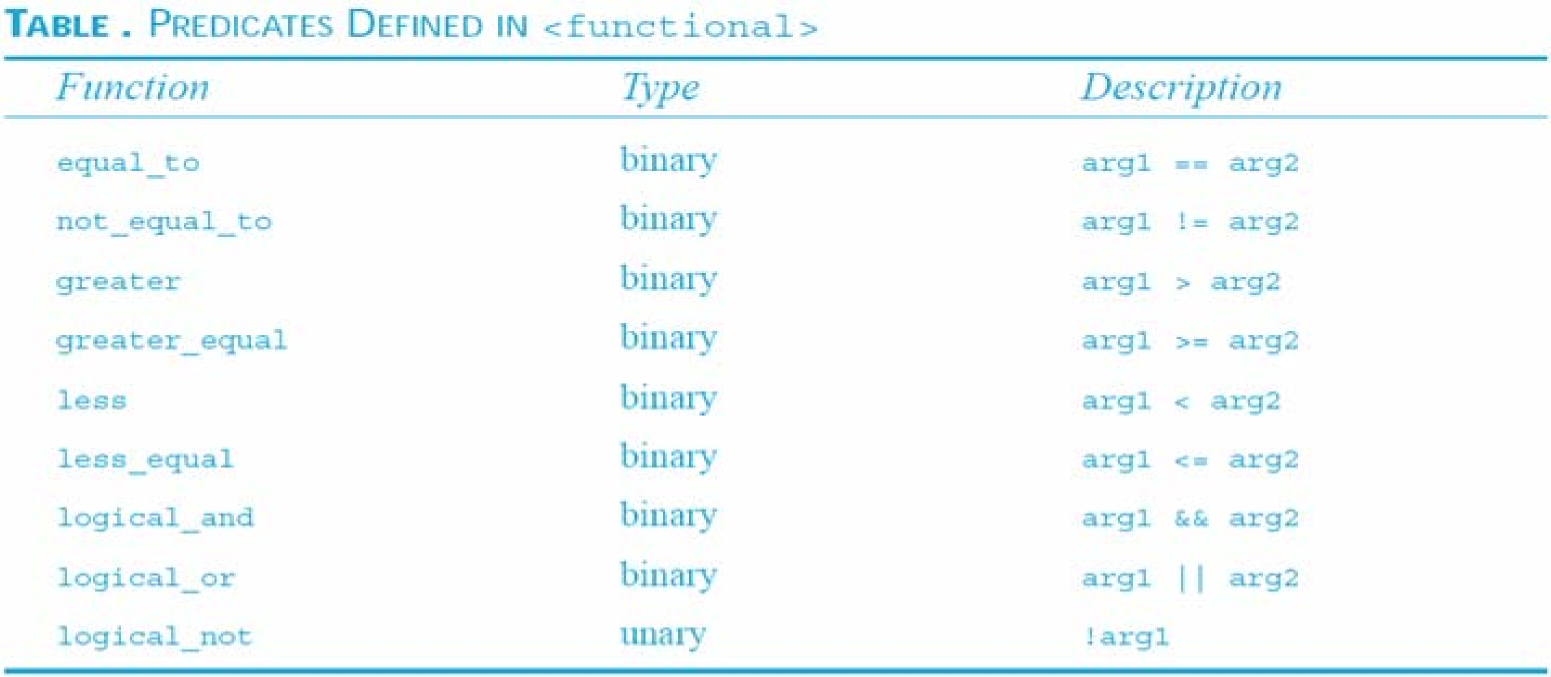


TABLE . PREDICATES DEFINED IN <functional>

Function	*Type*	*Description*
equal_to	binary	arg1 == arg2
not_equal_to	binary	arg1 != arg2
greater	binary	arg1 > arg2
greater_equal	binary	arg1 >= arg2
less	binary	arg1 < arg2
less_equal	binary	arg1 <= arg2
logical_and	binary	arg1 && arg2
logical_or	binary	arg1 || arg2
logical_not	unary	!arg1

```
template<class T>
class equal_to : binary_function<T, T, bool> {
bool operator()(T& arg1, T& arg2) const { return arg1 == arg2; }
};
```