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## STL Containers – Supplementary Notes

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1. **Every container allocates and manages its own storage.**
2. **Type definitions common to all containers:**

* C::value\_type type of values held in container
* C::reference value\_type&
* C::const\_reference
* C::iterator
* C::const\_iterator
* C::reverse\_iterator
* C::const\_reverse\_iterator
* C::difference\_type difference between iterators
* C::size\_type size of container

1. **Member functions common to all containers:**

* C( ) default constructor
* C(c), C c2(c1) copy constructor
* ~C( ) destructor
* c.begin() returns an iterator to first element
* c.end() returns an iterator after last element
* c.rbegin() returns a reverse iterator to last elem.
* c.rend() returns a reverse iterator before first elem.
* c1 == c2 equality comparison for same type cont.
* c1 != c2 “
* c.size() returns number of elements. in cont.
* c.max\_size() returns size() of largest number of elements.
* c.empty() returns true if cont. is empty
* c1 < c2 lexicographic comparison
* c1 > c2 “
* c1 <= c2 “
* c1 >= c2 “
* c1 = c2 assignment operation
* c1.swap(c2) swaps two containers

1. **Sequence containers**

* vector simulates an expandable array, occupying contiguous memory
* list based on doubly linked list
* deque a double ended queue, which uses a directory managing blocks of  
   contiguousmemory

1. **Member functions common to all sequence containers:**

* C(n,t) constructs a sequence of n copies of t
* C(iter1,iter2) constructs a sequence equal to the range [iter1,iter2)
* c.insert(iter,t) inserts a copy of t before iter. Returns an iter to t.
* c.insert(iter,n,t) inserts n copies of t before iter.
* c.insert(iter1,iter2,iter3) inserts the sequence [iter2,iter3) before iter1
* c.erase(iter) erases the element pointed to by iter
* c.erase(iter1,iter2) erases elements in range [iter1,iter2)

1. **Invalidation of iterators**

* **Invalidation of iterators into vectors:**
* insertion in a vector invalidates iterators from the point of insertion to the end of the vector.
* if insertion causes reallocation to provide more memory then all iterators become invalid.
* erase invalidates all iterators at and past the point of erasure.
* a safe strategy is to assume that any iterator into a vector becomes invalid after either insertion or erasure.
* **Invalidation of iterators into deques:**
* insertion and erasure in the interior invalidates all iterators.
* **Invalidation of iterators into lists:**
* list insertions never invalidate iterators and erase invalidates only iterators pointing to the erased items.
* **Use of invalid iterators:**
* The only safe things you can do with an invalid iterator is to reinitialize it by assigning a new iterator value to it or destroy it.

1. **Sorted associative containers (all are based on balanced red-black tree):**

* set set of elements sorted by value with no duplicates
* multi-set set of elements sorted by value with duplicates
* map set of <key,value> pairs sorted on key with no duplicates
* multi-map set of <key,value> pairs sorted on key with duplicates

1. **Types common to all sorted associative containers:**

* C::key\_type type of keys used to instantiate C
* C::key\_compare type of the comparison type used to instantiate C
* C::value\_compare type for comparing objects of C::value\_type

1. **Invalidation of iterators with associative containers:**

* insertion does not invalidate any iterators referring to container elements.
* erasure invalidates only iterators pointing to erased elements.

1. **Member functions common to all sorted associative containers:**

* C( ) void constructor
* C(comp) constructs empty container using comp for comparisons
* C(iter1,iter21) constructs empty container and inserts elements from [iter1,iter2) into it.
* C(iter1,iter2,comp) same as above except that comp is used for comparisons.
* c.key\_comp() returns c’s key comparison object
* c.value\_comp() returns c’s value comparison object
* c.insert(t) for sets and maps inserts t if and only if there is no equivalent key   
   stored, returns pair<iterator,bool>. The bool indicates if insertion  
   succeeded and iterator points to the element equivalent to t.  
   for multi-sets and multi-maps inserts t and returns an iterator pointing  
   to the inserted t
* c.insert(iter,t) same as above except that iter is a hint about where to start search
* c.insert(iter1,iter2) inserts elements from the sequence [iter1,iter2)
* c.erase(k1) erases all elements in the container with key equal to k1. Returns the   
   number of elements erased.
* c.erase(iter) erases the element pointed to.
* c.erase(iter1,iter2) erases all elements in the range [iter1,iter2).
* c.find(k1) returns an iterator pointing to an element with key equal to k1 or to   
   c.end( ) if no such element is found.
* c.count(k1) returns the number of elements with key equivalent to k1
* c.lower\_bound(k1) returns an iterator pointing to first element with key not less than k1.
* c.upper\_bound(k1) returns an iterator pointing to first element with key greater than k1.
* c.equal\_range(k1) returns a pair of iterators with first lower\_bound and second  
   upper\_bound

## STL Iterators

1. **Iterators extend the functionality of native pointers.**

* Any container, c, defines valid iterators pointing to the first element, returned by c.begin() and one past the last element, returned by c.end().
* an iterator range is a pair of iterators that serve as the beginning and end markers of some operation on container values. Range [iter1, iter2) includes the values pointed to by iter1 through the value pointed to by the predecessor of iter2.
* iterators can be dereferenced, e.g., if iter is an iterator for some container c, \*iter returns value\_type whenever it is in the range [c.begin(), c.end())
* if iter is in the range [c.begin(), c.end()) then either iter++ stays in the range or is equivalent to c.end().
* iterators can be mutable or constant depending on whether the result of operator\* acts like a reference or a reference to a const.

1. **Input iterator requirements:**

* I(i) copy constructor
* i == j returns true if iterator i is equivalent to iterator j
* i != j returns true if and only if i == j returns false
* \*i returns value\_type if dereferenceable. If i == j then it must be true that   
   \*i == \*j. Note: don’t attempt to write to \*i as it may not be an l-value.
* i->m equivalent to (\*i).m
* ++i returns an iterator pointing to the successor element to \*i or to c.end();
* i++ ` returns i then points to the successor of \*i or to c.end()
* Algorithms that use input iterators should be single-pass.

1. **Output iterator requirements:**

* I(i) copy constructor
* \*i = t t is assigned through the iterator.
* ++i returns an iterator pointing to the successor element to \*i or to c.end()
* i++ returns i then points to the successor of \*i or to c.end()
* The only valid use of \*i is on the left of an assignement. Algorithms that use output iterators should be single-pass.

1. **Forward iterator requirements:**

* I() void constructor, result may be a singular value
* I(i) result must satisfy i == I(i);
* i == j true if i is equivalent to j
* i != j true if i==j is false
* i = j result must satisfy i == j
* \*i returns value\_type if dereferenceable. If i == j then \*i == \*j must be true.  
   If i is mutable then \*i = t is valid.
* i -> m equivalent to (\*i).m
* ++i returns an iterator pointing to the successor element to \*i or to c.end()  
   i == j and i dereferenceable implies that ++i == ++ j.
* i++ returns i then points to the successor of \*i or to c.end()

1. **Bidirectional iterator requirements:**

* meets all requirements of Forward iterators.
* - - i Assume that there is a j such that ++j = i. Then - - i refers to the same element  
   as j. It must be true that --(++i) = i and if - -i == --j then i == j.
* i- - returns i then points to the predecessor of i

1. **Random access iterator requirements:**

* meets the requirements for a bidirectional iterator.
* i += n the result must be equivalent to incrementing i n times.
* i + n returns an iterator equivalent to i += n.
* i -= n the result must be equivalent to decrementing i n times.
* i – n returns an iterator equivalent to i -= n.
* i – j returns a value of type distance. If i + n = j then j – 1 == n
* i[n] equivalent to \*(i + n)
* i < j must be a total order relationship returning bool
* i > j must be a total order relationship returning true whenever i < j || i == j is  
   false
* i <= j must be a total order relationship equivalent to !(i > j)
* i >= j must be a total order relationship equivalent to !(i < j)

1. **Algorithms – Non modifying (Prata, C++ Primer Plus, Third Edition, Waite Group)**

|  |  |
| --- | --- |
| for\_each | Applies a non-modifying function object to each element in a range |
| find | Finds the first occurrence of a value in a range |
| find\_if | finds the first value satisfying a predicate test criterion in a range |
| find\_end | finds the last occurrence of a subsequence whose values match the values of a second sequence. Matching may be by equality or by applying a binary predicate. |
| find\_first\_of | Finds the first occurrence of any element of a second sequence that matches a value in the first sequence. Matching may be by equality or be evaluated with a binary predicate. |
| adjacent\_find | Finds the first element that matches the element immediately following it. Matching may be by equality or evaluated with a binary predicate. |
| count | Returns the number of times a given value occurs in a range. |
| count\_if | Returns the number of times a given value matches values in a range, with a match determined by using a binary predicate. |
| mismatch | Finds the first element in one range that does not match the corresponding element in a second range and returns iterators to both. Matching may be by equality or be evaluated with a binary predicate. |
| Equal | Returns true if each element in one range matches the corresponding element in a second range. Matching may be by equality or evaluated with a binary predicate. |
| search | Finds the first occurrence of a subsequence whose values match the values of a second sequence. Matching may be by equality or by applying a binary predicate. |
| search\_n | Finds the first subsequence of n elements that each match a given value. Matching may be by equality or applying a binary predicate. |

**Example:**

template <class T>

class Sum

{

Sum() : sum\_(0) {}

void operator()(T& t) { sum\_ += t; }

result() { return sum\_; }

private: T sum\_;

}

std::list<int> li;

// push on some elements

// foreach is the only algorithm that returns its operation, e.g., Sum()

int sum = foreach(li.begin(),li.end(),Sum()).result();

1. **Algorithms – Modifying (Prata, C++ Primer Plus, Third Edition, Waite Group)**

|  |  |
| --- | --- |
| copy | Copies elements from a range to a location identified by an iterator. |
| copy\_backward | Copies elements from a range to a location identified by an iterator. Copying begins at the end of the range and proceeds backwards. |
| Swap | Exchanges two values stored at locations specified by references. |
| Swap\_ranges | Exchanges corresponding values in two ranges. |
| iter\_swap | Exchanges two values stored at locations specified by iterators. |
| transform | Applies a function object to each element in a range (or to each pair of elements in a pair of ranges), copying the return value to the corresponding location of another range. |
| replace | Replaces each occurrence of a value in a range with another value. |
| replace\_if | Replaces each occurrence of a value in a range with another value if a predicate function object applied to the original value returns true. |
| replace\_copy | Copies one range to another, replacing each value for which a predicate function object is true with an indicated value. |
| fill | Sets each value in a range to an indicated value. |
| fill\_n | Sets n consecutive elements to a value. |
| generate | Sets each value in a range to the return value of a generator, which is a function object that takes no arguments. |
| generate\_n | Sets the first n values in a range to the return value of a generator, which is a function object that takes no arguments. |
| remove | Removes all occurrences of a value from a range and returns a past-the-end iterator for the resulting range. |
| remove\_if | Removes all occurrences of values for which a predicate object returns true from a range and returns a past-the-end iterator for the resulting range. |
| remove\_copy | Copies elements from one range to another, omitting elements that equal a specified value. |
| remove\_copy\_if | Copies elements from one range to another, omitting elements for which a predicate function object returns true. |
| unique | Reduces each sequence of two or more equivalent elements in a range to a single element. |
| unique\_copy | Copies elements from one range to another, reducing each sequence of two or more equivalent elements to one. |
| reverse | Reverses the elements in a range. |
| reverse\_copy | Copies a range in reverse order to a second range. |
| Rotate | Treats a range as a circular ordering and rotates the elements left. |
| Rotate\_copy | Copies one range to another in a rotated order. |
| Random\_shuffle | Randomly rearranges the elements in a range. |
| partition | Places all the elements that satisfy a predicate function object before all elements that don’t. |
| Stable\_partition | Places all the elements that satisfy a predicate function object before all elements that don’t. The relative order of elements in each group is preserved. |

1. **Sorting & Related Operations (Prata, C++ Primer Plus, Third Edition, Waite Group)**

|  |  |
| --- | --- |
| sort | Sorts a range. |
| stable\_sort | Sorts a range, preserving the relative order of equivalent elements. |
| partial\_sort | Partially sorts a range, providing the first n elements of a full sort. |
| partial\_sort\_copy | Copies a partially sorted range to another range. |
| nth\_element | Given an iterator into a range, finds the element that would be there if the range were sorted, and places that element there. |
| lower\_bound | Given a value, finds the first position in a sorted range before which the value can be inserted while maintaining the ordering. |
| upper\_bound | Given a value, finds the last position in a sorted range before which the value can be inserted while maintaining the ordering. |
| equal\_range | Given a value, finds the largest subrange of a sorted range such that the vlue can be inserted before any element in the subrange without violating the ordering. |
| binary\_search | Returns true if a sorted range contains a value equivalent to a given value, and false otherwise. |
| merge | Merges two sorted ranges into a third range. |
| in-place\_merge | Merges two consecutive sorted ranges in place. |
| includes | Returns true if every element in one set also is found in another set. |
| set\_union | Constructs the union of two sets, which is a set containing all elements present in either set. |
| set\_intersection | Constructs the intersection of two sets, which is a set containing only those elements found in both sets. |
| set\_difference | Constructs the difference of two sets, which is a set containing only those elements found in the first set but not the second. |

|  |  |
| --- | --- |
| set\_symmetric\_difference | Constructs a set consisting of elements found in one set or the other, but not both. |
| make\_heap | Converts a range to heap. |
| push\_heap | Adds an element to a heap. |
| pop\_heap | Removes the largest element from a heap. |
| sort\_heap | Sorts a heap. |
| min | Returns the lesser of two values. |
| max | Returns the greater of two values. |
| min\_element | Finds the first occurrence of the smallest value in a range. |
| max\_element | Finds the first occurrence of the largest value in a range. |
| lexicographic\_compare | Compares two sequences lexicographically, returning true if the first sequence is lexicographically less than the second, and false otherwise. |
| next\_permutation | Generates the next permutation in a sequence. |
| previous\_permutation | Generates the preceding permutation in a sequence. |

1. **Predefined Function Objects (Josuttis, C++ Standard Library, Addison-Wesley)**

|  |  |
| --- | --- |
| **Expression** | **Effect** |
| negate<T>() | - param |
| plus<T>() | param1 + param2 |
| minus<T>() | param1 – param2 |
| multiplies<T>() | param1 \* param2 |
| divides<T>() | param1 / param2 |
| modulus<T>() | param1 % param2 |
| equal\_to<T>() | param1 == param2 |
| not\_equal\_to<T>() | param1 != param2 |
| less<T>() | param1 < param2 |
| greater<T>() | param1 > param2 |
| less\_equal<T>() | param1 <= param2 |
| greater\_equal<T>() | param1 >= param2 |
| logical\_not<T>() | ! param |
| logical\_and<T>() | param1 && param2 |
| logical\_or<T>() | param1 || param2 |

**Example:**

std::list<int> li;

// push on some elements

std::list<int>::iterator itPos;

// find first positive element in list

itPos = find\_if(li.begin(),li.end(),bind2nd(greater<int>(),0);