CS2141 – Software Development using C/C++

The Standard Template Library

STL Content

- Data Structures – Template classes for common structures such as lists and stacks
- Iterators – A generalization of a pointer used to access containers without knowing anything about the internal structure of the container
- Function Objects – Objects that overload **`operator()`** so they can be used like a function
- Generic Algorithms – Functions that can work with many different data structures

STL Data Structures

- There are several groups of data structures:
  - Sequence structures
    - List or array type things
    - Includes vectors, lists, and deques
  - Sequence adapters
    - Built on top of sequence structures
    - Includes stacks and queues
  - Associative structures
    - Store key-value pairs
    - Includes maps and sets

Vectors

- A **`vector`** is a resizable array
  - Provides efficient random access
  - Insertions and deletions in the middle are slow
- Vector constructors:
  - **`vector<T> v;`**
  - **`vector<T> v( int size );`**
  - **`vector<T> v( int size, T initial_value );`**

    Initializes elements to **`initial_value`**.
  - **`vector<T> v( vector<T> oldvector );`**

Vector Functions

- Accessing elements:
  - **`v[index]`** Return element at index.
  - **`v.at( index )`** Like **`[]`**, but does range checking.
  - **`v.front( )`** Return the first element.
  - **`v.back( )`** Return the last element.
- Size:
  - **`v.size( )`** Return number of elements.
  - **`v.empty( )`** Return true if empty.
  - **`v.resize( newsize )`** Set number of elements.

Vector Functions cont.

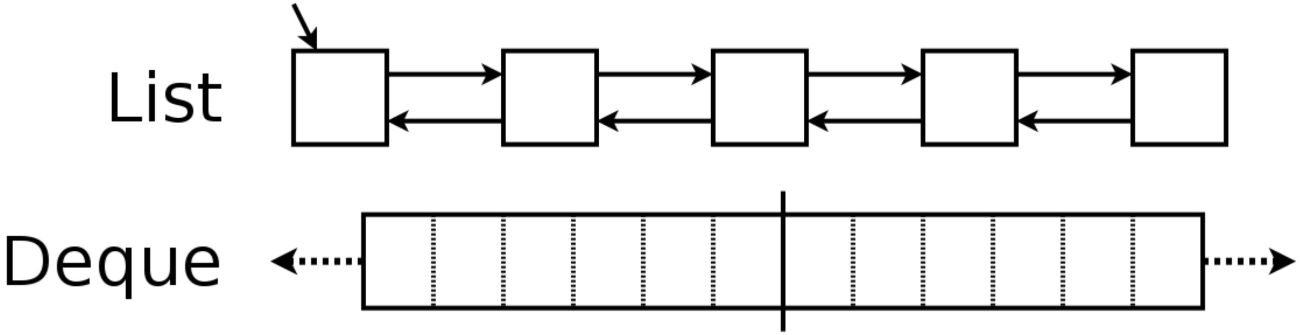
- Insert and remove:
  - **`v.push_back( value )`** Append value
  - **`v.pop_back( )`** Remove the last element
  - **`v[pos] = value`** Set element at pos to value
  - **`v.insert( iterator, value )`** Insert element at the position indicated by the iterator
  - **`v.erase( iterator )`** Remove the element at the position indicated by the iterator
  - **`v.clear( )`** Remove all elements from the vector

Example

```
#include <vector>          // Header for vectors
#include <iostream>
using namespace std;

int main( ) {
   vector<int> v;          // A vector that stores ints
   int i;

   while( !cin.eof( ) ) {  // Read any number of ints
      cin >> i;
      v.push_back( i );    // Store the ints in the vector
   }

   for( i = 0; i < v.size( ); ++i ) // Print out the
      cout << v[i] << “ “;          // vector one element
                                    // at a time.
   cout << endl;
}
```

Lists and Deques

- A **`list`** is a doubly linked list structure
  - Optimized for insertions and deletions
  - Does not allow random access (no **`[]`** operator)
- A **`deque`** is a double-ended vector
  - Operations at either end are efficient like **`list`**
  - Subscripting is efficient like a **`vector`**



Sequence Adapters

- The **stack** and **queue** both can take a sequence structure as a template parameter
    - Both use deques by default
    - A **vector** cannot be used with a **queue**
- They are adapters as they provide a specialized interface to a more general structure
    - Adapters do not provide iterators
    - Intended to only be used through their interfaces
- There is also a **priority_queue** type

Associative Structures

- A **`map`** stores key-value pairs
  - Map operations use a **`pair`** data type
    - **`pair.first`** returns the key
    - **`pair.second`** returns the value
- A **`set`** is like a **`map`**, but only stores keys
- Both are implemented as binary trees, so operations are very efficient
- A **`multi_map`** or **`multi_set`** allow keys to appear more than once in the structure

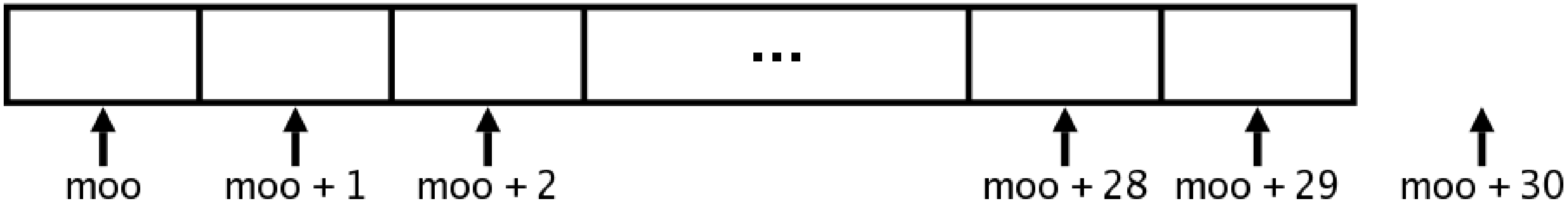
Iterators

- An iterator is a generic way of accessing a data structure without knowing anything about how the structure works
- Iterators are used a lot like pointers:
  - They can be dereferenced with the * operator
  - They can be incremented and decremented
  - They can be subscripted (sometimes)
- Pointers are iterators

Iterators cont.

- A pair of iterators refers to a range of locations:

```
int moo[30];
```

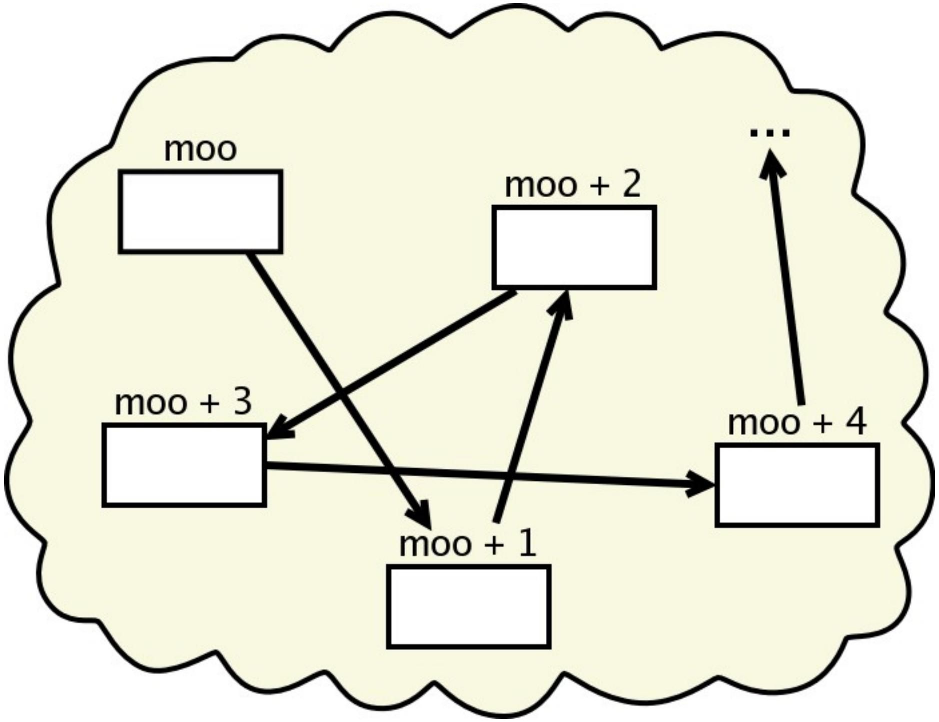


```
int * begin = moo;
int * end = moo + 30;
```

- The begin iterator refers to the first element in the data structure.
- The end iterator refers to **after** the last element.

Iterators cont.

- Iterators might access locations that are not necessarily contiguous in memory
- Iterators can be used without knowing anything about the underlying data structure



Iterators cont.

- **begin( )** and **end( )** are used to get iterators from an STL data structure
  - **begin( )** returns an iterator for the first element
  - **end( )** returns an iterator for after the last element

```
vector<int> v;
...
int sum = 0;
vector<int>::iterator start = v.begin( );
vector<int>::iterator stop = v.end( );
for( ; start != stop; ++start )
sum += *start;
```

Iterators cont.

- There are two major types of iterators:
    - Bi-directional
        - Can increment and decrement, but no random access
        - Returned by lists, sets, and maps
    - Random access:
        - Can do whatever - increment, decrement, subscript...
        - Returned by vectors, strings, and deques
- Some generic algorithms require random access iterators and can't be used with list, sets, or maps

Function Objects

- Any object overloading the parenthesis operator can be used as a function

```
class Bigger {
   public:
   Bigger( int v = 0 ) : val( v ) { }
   bool operator()( int test )
   { return test > val; }

   private:
   int val;
};

Bigger byte( 8 );
if( byte( 3 ) )...
```

Generic Algorithms

- STL generic algorithms are based on templates, iterators, and function objects, so they can be used with a wide variety of data structures
- One algorithm is find, which takes a start iterator, an end iterator, and a value to look for:

```
int nums[100];
...
int * pos = find( nums, nums + 100, 45 );
if( pos != (nums + 100) )
   cout << “Found 45 in the array” << endl;
else
   cout << “Couldn't find 45” << endl;
```

Generic Algorithms cont.

- Generic algorithms are just template functions:

```
template <class iterator, class T>
iterator find( iterator first, iterator last, T
& val )
{
   while( first != last && *first != val )
   ++first;
   return first;
}
```

- Some other algorithms:
  - **count, copy, sort, count_if, replace, generate, equal, fill, random_shuffle, search, reverse, inner_product, for_each, includes, max**