STL

- Generic programming
- An example – inserters, iterator-adapters, functors
- Efficiency
- Memory consuption characteristics
- Std::array
- Forward_list
- Unordered containers in C++11

Example: merge two files

```
#include <iostream>
#include <fstream>
#include <string>

using namespace std;

// simple merge
int main()
{
    string s1, s2;
    ifstream f1("file1.txt");
    ifstream f2("file2.txt");

    f1 >> s1; f2 >> s2;
    while (f1 || f2)
    {
        if (f1 && ((s1 <= s2) || !f2))
        {
            cout << s1 << endl;
            f1 >> s1;
        }
        if (f2 && ((s1 >= s2) || !f1))
        {
            cout << s2 << endl;
            f2 >> s2;
        }
    }
    return 0;
}
```

Example: naïve STL

```
#include <iostream>
#include <fstream>
#include <string>
#include <algorithm>    // merge( b1, e1, b2, e2, b3 [,opc_rend])
#include <vector>

using namespace std;
int main()
{
    ifstream if1("file1.txt");
    ifstream if2("file2.txt");

    string s;
    vector<string> v1;
    while ( if1 >> s ) v1.push_back(s);
    vector<string> v2;
    while ( if2 >> s ) v2.push_back(s);

    // allocate the space for the result
    vector<string> v3(v1.size() + v2.size());   // very expensive...

    merge( v1.begin(),v1.end(),v2.begin(),v2.end(),v3.begin());   // v3[i] = *c

    for ( int i = 0; i < v3.size(); ++i)
        cout << v3[i] << endl;

    return 0;
}
```

Example: inserters

```
#include <iostream>
#include <fstream>
#include <string>
#include <algorithm>
#include <vector>

using namespace std;

int main()
{
    ifstream if1("file1.txt");
    ifstream if2("file2.txt");

    string s;
    vector<string> v1;
    while ( if1 >> s ) v1.push_back(s);
    vector<string> v2;
    while ( if2 >> s ) v2.push_back(s);
    vector<string> v3;
    v3.reserve( v1.size() + v2.size() );    // allocates but not construct, size == 0

    merge(v1.begin(),v1.end(),v2.begin(),v2.end(),back_inserter(v3)); // v3.push_back(*c)

    for ( int i = 0; i < v3.size(); ++i)
        cout << v3[i] << endl;

    return 0;
}
```

Example: stream iterator

```
#include <iostream>
#include <fstream>
#include <string>
#include <algorithm>
#include <iterator>     // input- and output-iterators

using namespace std;

int main()
{
    ifstream if1("file1.txt");
    ifstream if2("file2.txt");

    // istream_iterator(if1) -> if1 >> *current
    // istream_iterator() -> EOF
    // ostream_iterator(of,x) -> of << *current << x
    merge( istream_iterator<string>(if1), istream_iterator<string>(),
           istream_iterator<string>(if2), istream_iterator<string>(),
           ostream_iterator<string>(cout,"\n") );

    return 0;
}
```

Example: comparator

```
#include <iostream>
#include <fstream>
#include <string>
#include <cctype>
#include <algorithm>
#include <iterator>

struct my_less  // function object: "functor"
{
    bool operator()(const std::string& s1, const std::string& s2)  {
        std::string us1 = s1;
        std::string us2 = s2;
        transform( s1.begin(), s1.end(), us1.begin(), toupper);  // TODO: use <locale>
        transform( s2.begin(), s2.end(), us2.begin(), toupper);
        return us1 < us2;
    }
};

int main()
{
    ifstream if1("file1.txt");
    ifstream if2("file2.txt");

    merge( istream_iterator<string>(if1), istream_iterator<string>(),
           istream_iterator<string>(if2), istream_iterator<string>(),
           ostream_iterator<string>(cout,"\n"), my_less() );
    return 0;
}
```

Example: template comparator

```
template <typename T>
class distr
{
public:
    distr(int l, int r, bool fl = true) : left_(l), right_(r), from_left_(fl), cnt_(0) { }
    // formal reasons: "compare" has two parameters of type T
    bool operator()( const T&, const T&)   {
        bool ret = from_left_;   // from_left_ is “smaller” currently
        const int max = from_left_ ? left_ : right_;
        if ( ++cnt_ == max )
        {
            cnt_ = 0;
            from_left_ = ! from_left_;
        }
        return ret;
    }
private:
    const int left_;  // read left_ element from left
    const int right_; // read right_ element from right
    int from_left_;   // start from left
    int cnt_;
};

   // ...
   istream_iterator<string>(if2), istream_iterator<string>(),
   ostream_iterator<string>(cout,"\n"), distr<std::string>(left,right) );
   // ...
```

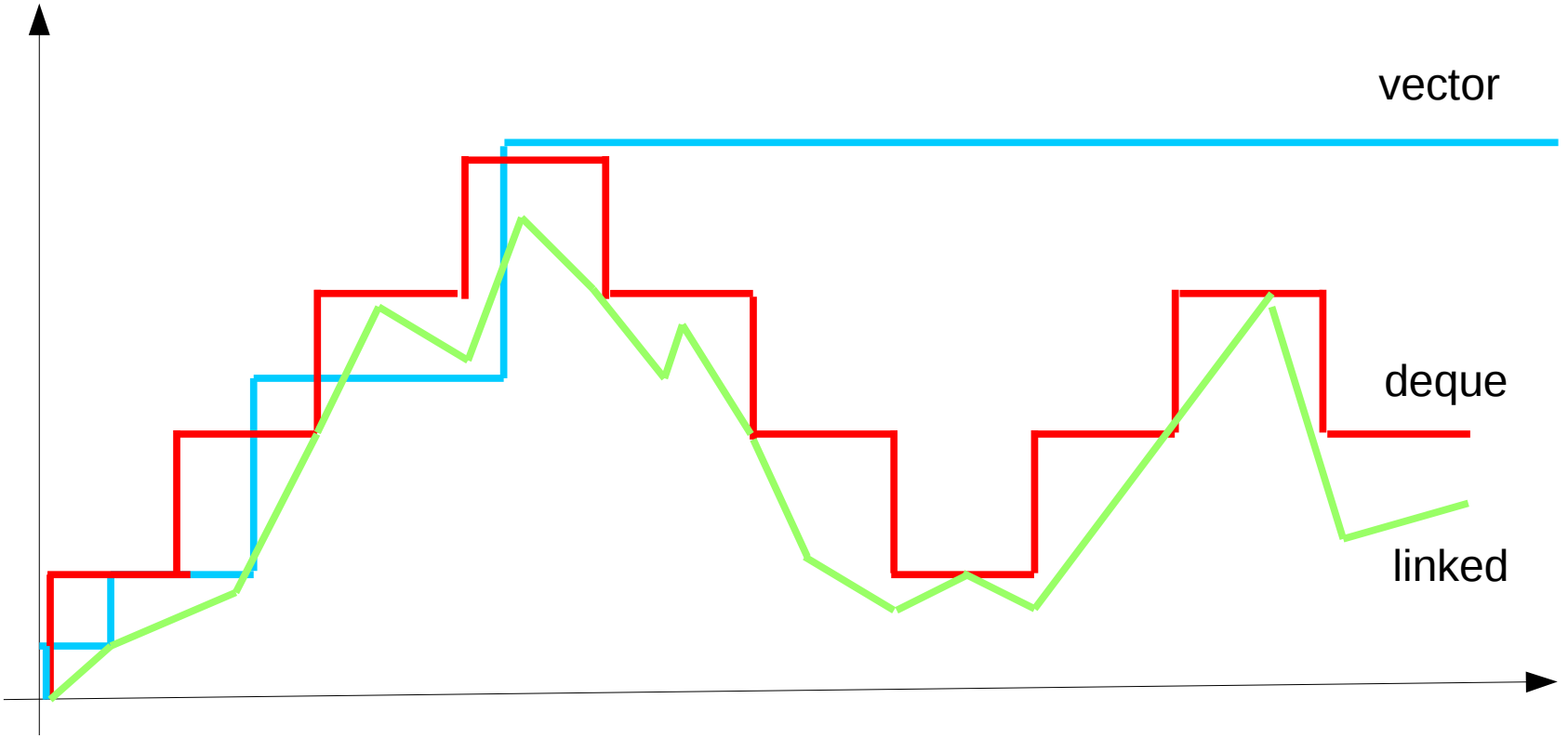
Vector vs Associative containers

```
#include <iostream>
#include <string>
#include <algorithm>
#include <set>
using namespace std;

int main()   /* print unique sorted elems  */
{
    set<string> coll( istream_iterator<string>(cin), istream_iterator<string>());
    copy( coll.begin(), coll.end(), ostream_iterator<string>(cout, "\n"));
}
```

```
#include <iostream>
#include <string>
#include <algorithm>
#include <vector>
using namespace std;

int main()   /* print unique sorted elems  */
{
    vector<string> coll( istream_iterator<string>(cin), istream_iterator<string>());
    sort (coll.begin(), coll.end());   // sort elements
    unique_copy (coll.begin(), coll.end(), ostream_iterator<string>(cout, "\n"));
}
```

```
        //  150.000 string:  vector solution is better with 10%
        //       + reserve:                                 15%
        // multiset + copy:                                 40%
```

Memory consumption



Vector size and capacity

```
int main()
{
    std::vector<int> v;
    std::cout << "Default-constructed capacity is " << v.capacity() << '\n';

    v.resize(100);
    std::cout << "Capacity of a 100-element vector is " << v.capacity() << '\n';

    v.clear();
    std::cout << "Capacity after clear() is " << v.capacity() << '\n';

    // std::vector<int>(v).swap(v); // C++98

    v.shrink_to_fit(); // C++11
    std::cout << "Capacity after shrink_to_fit() is " << v.capacity() << '\n';
}
```

```
Default-constructed capacity is 0
Capacity of a 100-element vector is 100
Capacity after clear() is 100
Capacity after shrink_to_fit() is 0
```

Std::array

```
#include <string>
#include <iterator>
#include <iostream>
#include <algorithm>
#include <array>

int main()
{
    // construction uses aggregate initialization
    std::array<int, 3> a1{ {1, 2, 3} }; // double-braces required in C++11 (not in C++14)
    std::array<int, 3> a2 = {1, 2, 3};  // never required after =
    std::array<std::string, 2> a3 = { std::string("a"), "b" };

    // container operations are supported
    std::sort(a1.begin(), a1.end());
    std::reverse_copy(a2.begin(), a2.end(), std::ostream_iterator<int>(std::cout, " "));

    std::cout << '\n';

    // ranged for loop is supported
    for(const auto& s: a3)
        std::cout << s << ' ';
}

// make_array and to_array are under consideration in standard
```

Std::forward_list

```
template <typename T, typename Alloc = allocator<T> >
class forward_list
{
public:
    void clear();
    iterator insert_after(const_iterator pos, const T& value); // +move, +interval
    iterator emplace_after(const_iterator pos, Args&&... args);
    iterator erase_after(const_iterator pos); // +interval
    void push_front(const T& value);          // +move
    void emplace_front( Args&&... args );
    void pop_front();
    void resise(size_type count); void resise(size_type count, const T& value);
    void swap(forward_list& other);

    iterator before_begin(), begin(), end();
    bool empty();

    void merge(forward_list&& other, Compare comp);
    void splice_after(const_iterator pos, forward_list& other);
    void remove(const T& value);
    void remove_if(UnaryPredicate p);

    void reverse();
    void unique(BinaryPredicate p);
    sort(Compare comp);

    // no reverse iteration
    // no back() or push_back()
    // no size()
};
```

Hash-based containers

- Unordered_map
- Unordered_set
- Unordered_multimap
- Unordered_multiset

std::unordered_map

```
#include <unordered_map>
#include <string>

using namespace std;

int main()
{
    unordered_map<string, string> hashtable;
    hashtable.emplace("www.zolix.hu", "212.92.23.158");
    hashtable.insert(make_pair("www.elte.hu", "212.92.23.159"));

    cout << "IP Address: " << hashtable["www.zolix.com"] << endl;

    for (auto &obj : hashtable)
    {
        cout << obj.first << ": " << obj.second << endl;
    }

    // returns std::unordered_map<std::string,double>::const_iterator
    auto it = hashtable.find(“www.elte.com”);
    if (hashtable.end() != it)   // hashtable.count(“www.elte.com”) > 0
    {
        cout << it->first << ": " << it->second << endl;
    }
    return 0;
}
```

std::unordered_map

```
#include <unordered_map>
#include <string>

class MyClass
{
    std::string name;
    int         age;
public:
    Bool operator==(const MyClass& rhs) { ... }   // should be reflexive
    // ...
};
class MyClassHash
{
public:
    size_t operator()(const MyClass& m) const
    {
        return std::hash<std::string>()(m.name) ^ hash<int>()(m.age);
    }
};
int main()
{
    MyClass jim(...), joe(...);
    unordered_map<MyClass, double> salary;
    hashtable.emplace( jim, 20000);
    hashtable.emplace( joe, 22000);
    // ...
}
```

Load factor

- Average insert/find is constant
- Worst-case: linear in container size
- Iterators are invalidated only on rehash
- Load factor == size() / bucket_count() // default 1.0
- Control of buckets:
  - size_type bucket_count() const; // #of buckets
  - float max_load_factor() const; // get max load factor
  - void max_load_factor(float z); // set max load factor
  - size_type bucket_size (size_type n) const; // #of bucket n
  - size_type bucket(const key_t& key) const; // where key goes?
  - void rehash(size_type n); // sets #of buckets

std::unordered_map

```
// unordered_map::bucket_count
#include <iostream>
#include <string>
#include <unordered_map>

int main ()
{
  std::unordered_map<std::string,std::string> mymap = {
       {"house","maison"},{"apple","pomme"},{"tree","arbre"},
       {"book","livre"},{"door","porte"},{"grapefruit","pamplemousse"}
  };
  unsigned n = mymap.bucket_count();
  std::cout << "mymap has " << n << " buckets.\n";

  for (unsigned i=0; i<n; ++i) {
    std::cout << "bucket #" << i << " contains: ";
    for (auto it = mymap.begin(i); it!=mymap.end(i); ++it)
      std::cout << "[" << it->first << ":" << it->second << "] ";
    std::cout << "\n";
  }
}
mymap has 7 buckets.
bucket #0 contains: [book:livre] [house:maison]
bucket #1 contains:
bucket #2 contains:
bucket #3 contains: [grapefruit:pamplemousse] [tree:arbre]
bucket #4 contains:
bucket #5 contains: [apple:pomme]
bucket #6 contains: [door:porte]
```

Load factor

```
// unordered_map::max_load_factor
int main ()
{
  std::unordered_map<std::string,std::string> mymap = {
    {"Au","gold"},{"Ag","Silver"},{"Cu","Copper"},{"Pt","Platinum"}
  };

  std::cout << "current max_load_factor: " << mymap.max_load_factor() << std::endl;
  std::cout << "current size: " << mymap.size() << std::endl;
  std::cout << "current bucket_count: " << mymap.bucket_count() << std::endl;
  std::cout << "current load_factor: " << mymap.load_factor() << std::endl;

  float z = mymap.max_load_factor();
  mymap.max_load_factor ( z / 2.0 );

  std::cout << "new max_load_factor: " << mymap.max_load_factor() << std::endl;
  std::cout << "new size: " << mymap.size() << std::endl;
  std::cout << "new bucket_count: " << mymap.bucket_count() << std::endl;
  std::cout << "new load_factor: " << mymap.load_factor() << std::endl;
  return 0;
}
current max_load_factor: 1
current size: 4
current bucket_count: 5
current load_factor: 0.8
new max_load_factor: 0.5
new size: 4
new bucket_count: 11
new load_factor: 0.363636
```

Std::unordered_multi...

```
// unordered_multiset::equal_range

#include <iostream>
#include <string>
#include <unordered_set>

int main ()
{
  std::unordered_multiset<std::string> myums =
                        {"cow","pig","pig","chicken","pig","chicken"};

  auto myrange = myums.equal_range("pig");

  std::cout << "These pigs were found:";

  while ( myrange.first != myrange.second ) {
      std::cout << " " << *myrange.first++;
  }
  std::cout << std::endl;

  return 0;
}
```