CSCI251 Advanced Programming

Generic Programming V: The Standard Template Library (STL) Continue...

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STL

- STL contains six major kinds of building blocks, implemented using templates:
  - Containers.
  - Iterators.
  - Generic algorithms.
  - Function objects.
  - Adaptors.
  - Allocators.

Generic algorithms

- Perform common operation:
  - Finding, sorting, searching,…
- Operation is independent of the data type
- Algorithms are applied to containers through the iterators
  - they operate through the iterators and they are container independent.
  - Note that: they usually don't add NEW elements to the original sequence

Generic algorithms

```
#include <algorithm>
```

- Most of the algorithms take one of the following four forms:

```
alg(beg, end, other args);
alg(beg, end, dest, other args);
alg(beg, end, beg2, other args);
alg(beg, end, beg2, end2, other args);
```

- The arguments *dest*, *beg2*, and *end2*, are used to reference a destination, or a second input sequence.

Algorithm categories

- Non-modifying sequence operations:
  - e.g. `find`.
- Modifying sequence operations:
  - E.g. `copy`.
- Partitioning operations
- Sorting operations
- Binary search operations (on sorted ranges)
- Set operations (on sorted ranges)
- Heap operations
- Minimum/maximum operations
- Numeric operations

http://en.cppreference.com/w/cpp/algorithm

Complexity

- The details on the algorithms at http://en.cppreference.com/w/cpp/algorithm indicate their complexity.
- For example:
  - next_permutation(see next)
  - Complexity: At most N/2 swaps, where N = std::distance(first, last).

next_permutation

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

int main()
{
    std::string s = "abcd";
    std::sort(s.begin(), s.end());
    do {
        std::cout << s << '\n';
    } while(next_permutation(s.begin(), s.end()));
}
```

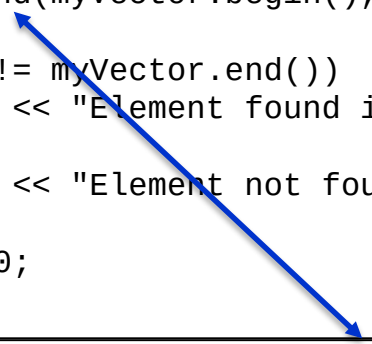
Sort

- Sorts the elements in the range [first, last) in non-descending order
- Complexity: *O(N·log(N))*
- *Example:*

```
#include <algorithm>
#include <iostream>
#include <array>
using namespace std;
int main()
{
   std::array<int, 10> s = {5, 7, 4, 2, 8, 6, 1, 9, 0, 3};
   std::sort(s.begin(), s.end());
   for (auto a = s.begin(); a!=s.end(); a++)
    cout<<*a<<endl;
}
```

Finding

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

int main()
{
  int myInts[] = { 10, 20, 30, 40 };

  vector<int> myVector (myInts,myInts+4); // vector of above ints
  vector<int>::iterator it; // vector iterator

  it = find(myVector.begin(), myVector.end(), 30);

  if (it != myVector.end())
     cout << "Element found in myVector: " << *it << '\n';
  else
     cout << "Element not found in myVector\n";

  return 0;
}
```



```
if (map.find(key) != map.end())
```

Function objects

- Classes that have an overloaded `operator()`
- In the context of STL there are some specific templated function objects classes that are used.
- There is a list at: http://en.cppreference.com/w/cpp/utility/functional

Function objects

- We can, for example, take a container (say a vector), and apply operation using its iterator and a function object ( ).
- The function object tells you how to do the individual operation for each iterator.

Function objects

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

void PrintFun(int n)
{
   cout << n << ' ';
}

class PrintObj
{
public:
   void operator()(int n)
   {
      cout << n << ' ';
   }
};
```

```
void Add3(int &n)
{
   n += 3;
}

class AddObj
{
public:
   AddObj(int number) : number_(number)
   {

   }
   void operator()(int &n)
   {
      n += number_;
   }

private:
   int number_;
};
```

Function objects

```
class GreaterObj
{
public:
    GreaterObj(int number) : number_(number)
    {

    }
    bool operator()(int n)
    {
        return n > number_;
    }
private:
    int number_;
};
```

Function objects

```
int main(void)
{
    int a[] = {1, 2, 3, 4, 5};
    vector<int> v(a, a + 5);

    //for_each(v.begin(), v.end(), PrintFun);

    for_each(v.begin(), v.end(), PrintObj());

    /*for_each(v.begin(), v.end(), Add3);
    for_each(v.begin(), v.end(), PrintFun);
    cout<<endl;*/

    for_each(v.begin(), v.end(), AddObj(5));
    for_each(v.begin(), v.end(), PrintFun);

    cout << count_if(a, a + 5, GreaterObj(3)) << endl;
    return 0;
}
```

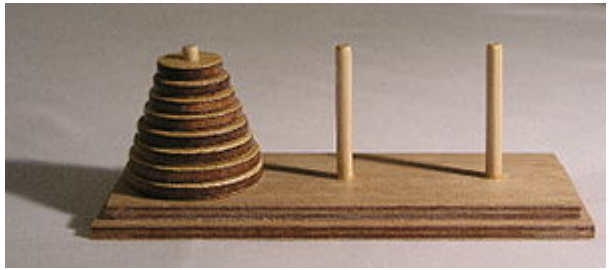
Adaptors

- an adaptor is a mechanism for making one thing act like another
- There are three sequential container adaptors:
  - Stack: LIFO.
  - Queue: FIFO.
  - Priority_queue: Prioritises based on, by default, <.

Adaptors

- As an example; the stack adaptor turns a sequential container, other than `array` or `forward_list`, and makes it operate like a stack.

- Tower of Hanoi - Stack



https://en.wikipedia.org/wiki/Tower_of_Hanoi

Allocators

- The library class `allocator` is used to allocate unconstructed memory.
- main purposes: decouple memory allocation from object construction.
  - we can allocate memory in large chunks and pay the overhead of constructing the objects only when we actually need to create them.

Allocators vs `new`

- The use of `new` is constrained in that it combines allocating memory with constructing an object, or objects, in that memory.
- an allocator allows these two operations to be separated.

- You only use/destroy what you construct.

Allocators

- Vector: the use of pop removes an element but doesn't free the associated memory.
- We can use the following member functions:
  - Size: Returns the number of elements in the vector.
    - myints.size()
  - Capacity: Returns the size of the storage space currently allocated for the vector

Example (dynamic change)

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

int main ()
{
  //std::vector<int>::size_type sz;

  std::vector<int> myvec;
  auto sz = myvec.capacity();
  std::cout << "making myvec grow:\n";
  for (int i=0; i<100; ++i) {
    myvec.push_back(i);
    std::cout<<myvec.size();
    if (sz!=myvec.capacity()) {
      sz = myvec.capacity();
      std::cout << "capacity changed: " << sz << '\n';
    }
  }
}
```

Allocators

- Instances of the class allocator can be use to provide type-aware allocation of raw, unconstructed, memory.
- We defined an allocator object for objects of *type T* as follows:

```
allocator<T> a;
```

- The operations for allocation, deallocation, creation and destruction are paired

Allocators

`auto const p = a.allocate(n);`	Allocates raw, unconstructed memory to hold n objects of type `T`, and sets up `p` to point to it.
`a.construct(p, args);`	Calls the constructer for objects of type T, associated with the `T*` pointer `p`.
`a.destroy(p);`	Calls the destructor on the object pointed to by the `T*` pointer `p`.
`a.deallocate(p,n);`	Deallocates the memory of `n` type `T` objects pointed to by `p`.

Allocators

```
#include <iostream>
#include <vector>
#include <string>
#include <algorithm>
using namespace std;
int main()
{
allocator<string> alloc;
auto const p = alloc.allocate(5);
auto q=p;
alloc.construct(q++);
alloc.construct(q++, 10, 'c');
alloc.construct(q++, "hi");
auto r=p;
do
cout << *r << endl;
while (++r != q);
Cout<<“done”<<endl;
while (q != p)
alloc.destroy(--q);
```

```
q=p; r=p;
alloc.construct(q++, 10, 'a');
alloc.construct(q++, "hi again");
do
cout << "here" << *r << endl;
while (++r != q);

alloc.deallocate(p, 5);
}
```

Practices