The Standard C++ Library

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Q: What types can we put in a template param?

A: Type which models the requested concept**.**

Concepts - Example

- Consider:

```
template<typename T> const T& min(const T& x,
                                  const T& y)
{
   return x < y? x : y;
}
```

- The user must provide a type that has a less-than operator (<) to compare two values of type T, the result of which must be convertible to a Boolean value

Concepts - Example

- Consider:

```
template<typename T> const T& min(const T& x,
                                  const T& y)
{
   return x < y? x : y;
}
```

- T ss-
  tl
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  t

The problem:
cryptic error messages
from the implementation of the function
instead of a clear error message

Concepts – What we would like it to be:

- **Not C++ syntax**:

```
template<LessThanComparable T> const T& min(const T& x,
                                            const T& y)
{
   return x < y? x : y;
}
```

- The user must provide a type that has a less-than operator (<) to compare two values of type T, the result of which must be convertible to a Boolean value

Concepts

- Concepts are not a yet part of the C++ language,

- Currently there is no (standard) way to declare a concept in a program, or to declare that a particular type is a model of a concept

- “were not ready” for C++11,C++14,C++17

- C++-20 ?

Concepts

- A concept is a list of requirements on a type.
- STL defines a hierarchy of concepts for containers, iterators, and element types.
- Concepts for element types include:

Equality Comparable -
types with operator== ,...

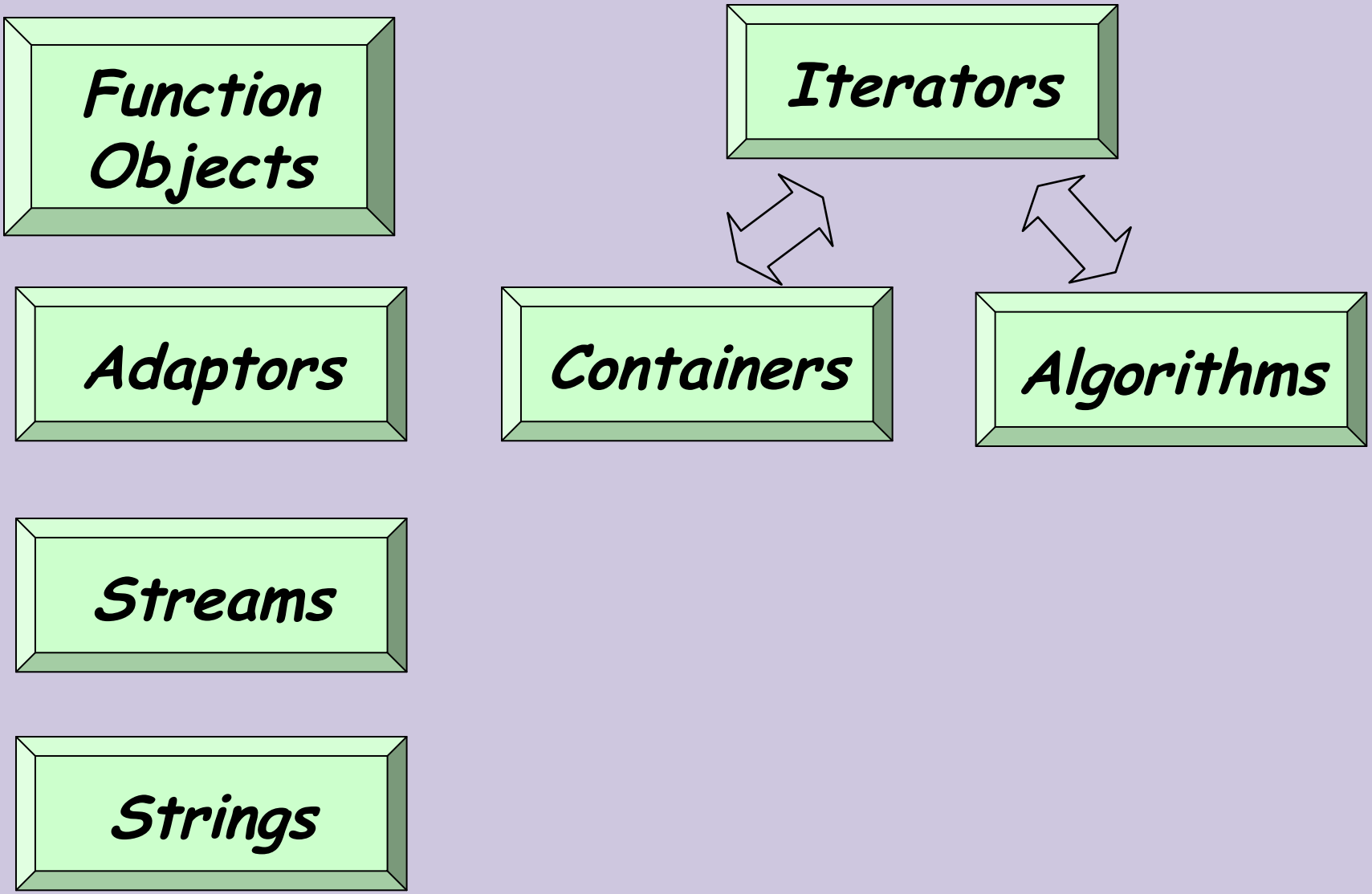
LessThan Comparable -
types with operator< ,...

Assignable -
types with operator=
and copy Ctor

Concepts

- Cleanly separate interface from implementation.
- Primitives can also conform to a concept.

Main Components



Containers

- Holds **copies** of elements.
- **Assumes** elements have: Copy Ctor & operator =
- The standard defines the **interface**.
- Two main classes
  - **Sequential containers**: list, vector,....
  - **Associative containers:** map, set ...

Assignable -
types with operator= and copy Ctor

Containers documentation

see
http://www.cplusplus.com/reference/stl/

Sequential Containers

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Sequential Containers

Maintain a linear sequence of objects.

forward_list - a singly-linked list.

list - a doubly-linked list.

- Efficient insertion/deletion in front/end/middle

vector - an extendable sequence of objects

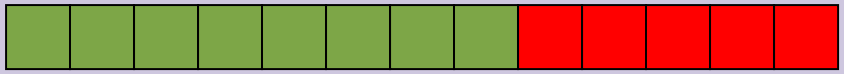
- Efficient insertion at end, and random access

deque – double-ended queue

- Efficient insertion/deletion at front/end
- Random access

array – fixed size, on the stack.

vector<T>



- Contiguous array of elements of type T
- Random access
- Can grow on as needed basis

```
std::vector<int> v(2);
v[0]= 45;
v[1]= 32;
v.emplace_back(60); //C++11
```

emplace_back / push_back Average Time Complexity

If we inserted **n** elements we paid:

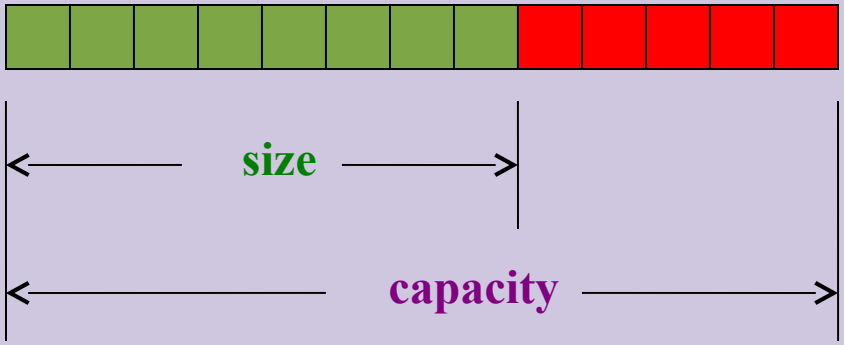
1+**2**+1+**4**+1+1+1+**8**+…+**n** =

O(n) + **1**+**2**+**4**+…+**n** =

O(n)

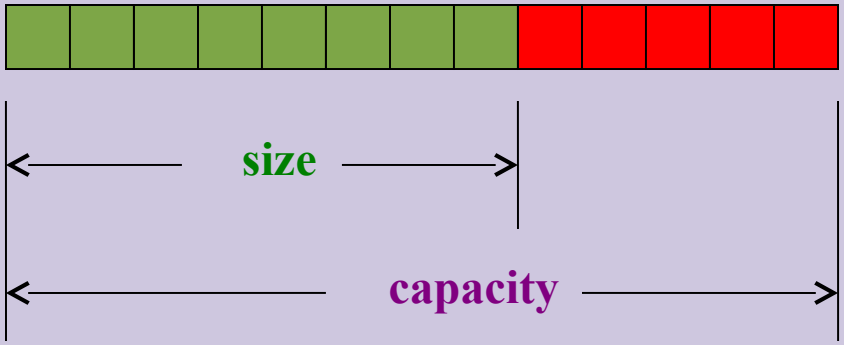
On average an each insertion cost O(1)

size and capacity



- The first “size” elements are constructed (initialized)
- The last “capacity - size” elements are uninitialized

size and capacity



- size_type **size**() const
- size_type **capacity**() const

C++ vs. Java

- Look at cplusplus documentation of vector.
- Look at Java documentation of Vector.
- Differences:
  - Simple class vs. interface and vtable.
  - Simple elements vs. class element.
  - Two accessors (with and without range check) vs. a single accessor

Creating vectors

- Empty vector:

```
std::vector<int> vec;
```

- vector with 10 ints each one of value int()==0:

```
std::vector<int> vec(10);
std::vector<int> vec(10,0); // better
```

- vector with 10 ints with the value of 42:

```
std::vector<int> vec(10, 42);
```

Creating vectors

- Empty vector:

```
std::vector<int> vec;
```

- vector with 10 ints each one of value **int()==0**:

```
std::vector<int>    vec(10);
std::vector<int>    vec(10,0); // better
```

Notice: int() is NOT a default constructor of int. Uninitialized ints (int k;) contain junk.

Creating vectors

- Empty vector:

```
std::vector<Fred> vec;
```

- vector with 10 default constructed Fred objects. i.e: 10 Fred() objects:

```
std::vector<Fred> vec(10);
```

- vector with 10 non-default constructed Fred objects:

```
std::vector<Fred> vec(10, Fred(5,7));
```

Creating vectors: C++11

- vector with different ints inside it:

```
std::vector<int> vec{1, 5, 10, -2, 0, 3};
```

- vector with different Fred objects:

```
std::vector<Fred> vec{Fred(5,7), Fred(2,1) }
```

Or

```
std::vector<Fred> vec{      {5,7},        {2,1} }
```

Associated types in vector

vector<typename T>::

- value_type - The type of object, T, stored
- reference - Reference to T
- const_reference - const Reference to T
- iterator - Iterator used to iterate through a vector *(how would you write it?)*
- …

Time complexity

- Random access to elements.
- Amortized constant time insertion and removal of elements at the end.
- Linear time insertion and removal of elements at the beginning or in the middle.
- vector is the simplest of the STL container classes, and in many cases the most efficient.

Adding elements

- Inserts a new element at the end:

  void push_back(const T&)

  - **a.push_back(t)** } amortized constant time

Adding elements-C++11

- Construct and insert a new element at the end:

```
template<typename… Args>
void emplace_back(Args&&… args)
```

  - **a.emplace_back(t)**

amortized constant time

Accessing elements

Without boundary checking:

- reference operator[](size_type n)
- const_reference operator[](size_type n) const

With boundary checking:

- reference at(size_type n)
- const_reference at(size_type n) const

What about checking boundaries only in DEBUG mode? - Linux

- g++ has a standard library in DEBUG mode, to activate it define _GLIBCXX_DEBUG

  (g++ -D_GLIBCXX_DEBUG …)

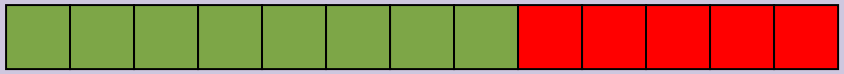
- stlport is an implementation of the standard library which includes DEBUG mode (havn't checked it myself yet):

http://www.stlport.org/

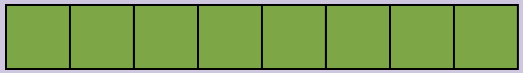
What about checking boundaries only in DEBUG mode? - MS

- In MSVS 2012 Debug build is automatically safe and Release build mode is not
- Other versions also have these kind of “Safe STL” modes but might require defining some flags to turn off or on.

vector<T> v



v.shrink_to_fit() // c++11



Associative Containers

- Supports efficient retrieval of elements (values) based on keys.

- (Typical) Implementation:

red-black binary trees

hash-table (added in c++11)

Sorted Associative Containers

set

- A set of unique keys ordered by <

map

- Associate a value to key (associative array)
- Unique value of each key, ordered by <

multiset, multimap

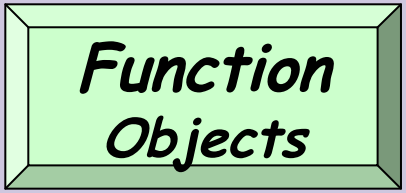
- Same, but allow multiple values

unordered_set, unordered_map

- Same, but without order (faster).

Sorted Associative Containers & Order

- Sorted Associative containers use operator< as default order
- We can control order by using our own comparison function
- To understand this issue, we need to use **function object**



Function Objects

Anything that can be called as if a function.

For example:

- Pointer to function
- A class that implements `operator()`
- Lambda expressions (c++11)

Example (folder 2)

```
class c_str_less {
public:
   bool operator()(const char* s1,
                   const char* s2) {
     return (strcmp(s1,s2) < 0);
   }
};

c_str_less cmp;  // declare an object
if(cmp("aa","ab"))
    …
if( c_str_less()("a","b") )
```

Creates temporary objects, and then call operator()

Template comparator example

```
template<typename T>
class less {
public:
  bool operator()(const T& lhs, const T& rhs)
  { return lhs < rhs; }
};

  less<int> cmp;  // declare an object
  if( cmp(1,2) )
    …
  if( less<int>()(1,2) )
    …
```

Creates temporary objects, and then call operator()

Using Comparators

```
// ascending order
// uses operator < for comparison
set<int>  s1;
set<int,less<int>> s1; // same

// descending order
// uses operator > for comparison
set<int,greater<int>> s2;
```

Using Comparators

```
set<int,MyComp> s3;
```

Creates a default constructed MyComp object.

```
MyComp cmp(42);
set<int,MyComp> s4(cmp);
```

Use given MyComp object.

Why should we use classes as function objects?

- So we get the “power” of classes.
- Examples:
  - Inheritance.
  - To parameterize our functions in run time or in compile time.
  - To accumulate information.