# The Standard C++ Library

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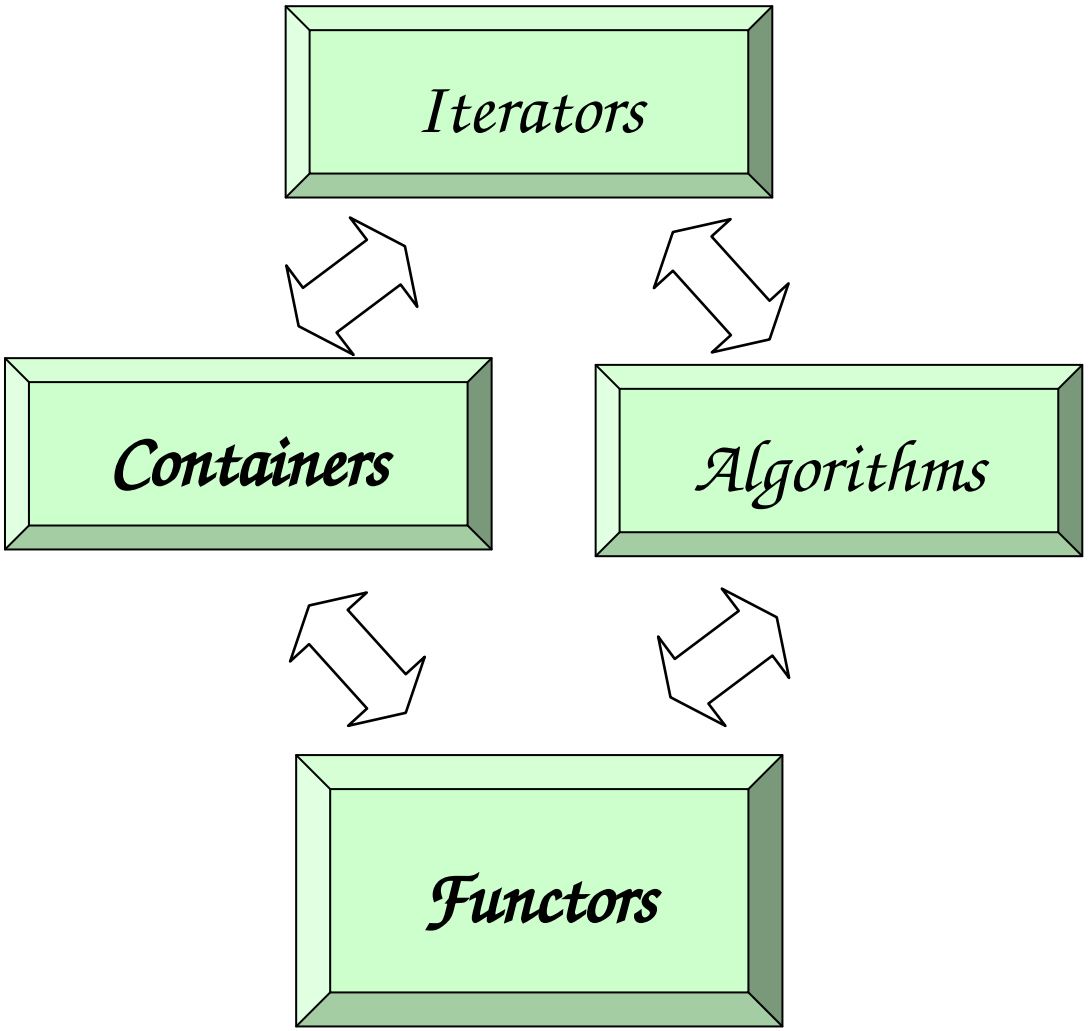
# Main Components



# *Containers*

**Fixed size:**

- pair, tuple, array

**Sequence containers:**

- forward_list, list, vector, deque, [basic_string]

**Associative containers:**

- set, multiset, map, multimap
- *unordered*_set, multiset, map, multimap

**Container adaptors:**

- stack, queue, priority_queue

# *Containers – General Rules*

- Holds **copies** of elements.
- **Assumes** elements have: Copy Ctor & operator =

**Assignable -**
types with operator= and copy Ctor

# *Pairs, Tuples*

(folder 0)

- Can hold a fixed number of elements of various types.
- Particularly useful in a **return** statement, to let your function return several values.
- Best style:

```
tuple<int,char,string> f () {
 return {5,'a',"hello"};
}
// in main:
auto [ii,cc,ss] = f();
```

- Other styles in folder 0.

# Tuple – when NOT to use

# STL: Sequential Containers

# Sequential Containers

## Objects are ordered by the user

| | insert first | insert middle | insert last | random access | iterate forward | iterate back | *find* | storage |
|---|---|---|---|---|---|---|---|---|
| **forward_list** | fast | fast | fast | slow | fast | slow | *slow* | heap |
| **list** | fast | fast | fast | slow | fast | fast | *slow* | heap |
| **deque** | fast | ~slow | fast | ~fast | fast | fast | *slow* | heap |
| **vector** | slow | slow | ~fast | fast | fast | fast | *slow* | heap |
| **basic_string** | slow | slow | ~fast | fast | fast | fast | *slow* | heap |
| **array** | - | - | - | fast | fast | fast | *slow* | stack |

# vector<T>

- Contiguous array of elements of type T
- Random access
- Can grow on as needed basis
- Most useful in practice

```
std::vector<int> v(200);
v[0]= 45;
v[100]= 32;
v.emplace_back(60);
```

# Vectors of ints

1)Creating an empty vector and filling it:

```
std::vector<int>   vec;
vec.push_back(42);
vec.emplace_back(42); // equivalent
```

2)Creating a vector with 10 ints with value 42:

```
std::vector<int>   vec(10,42);
std::vector<int>   vec(10); // default is 0
```

3)Initializing a vector like an array:

```
std::vector<int>   vec { 42, 52, 62 };
```

4)Initializing a vector from iterators:

```
std::vector<int>   v2(vec.begin(),vec.end());
```

# Vectors of objects

1)Creating an empty vector and filling it:

```
std::vector<MyClass>   vec;
vec.push_back(MyClass{42,43});
vec.emplace_back(42,43); // more efficient
```

2)Creating a vector with 10 objs:

```
std::vector<MyClass>  vec(10,MyClass{42,43});
std::vector<MyClass>  vec(10); // default ctor
```

3)Initializing a vector like an array (calls ctor):

```
std::vector<MyClass>  vec { {42,43}, {52}, {62,72} };
```

4)Initializing a vector from iterators:

```
std::vector<MyClass>  v2(vec.begin(),vec.end());
```

# push vs. emplace

- Inserts a new element at the end:

  void push_back(const T&)

  - **a.push_back(t)**

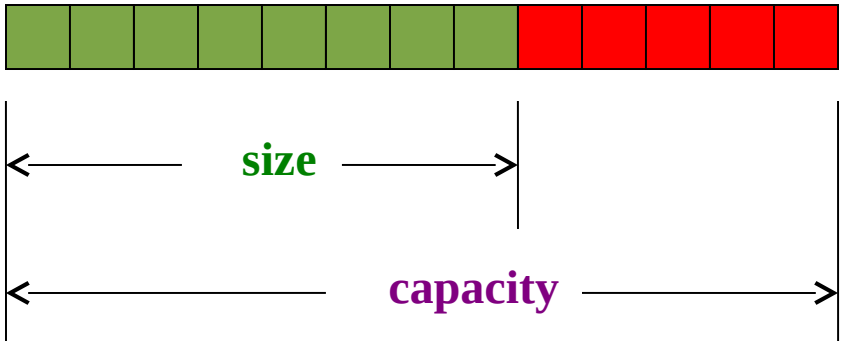
- Construct and insert a new element at end:

  template<typename… Args>

  void emplace_back(Args&&… args)

  - **a.emplace_back(t)**

# size and capacity




- **The first “size” elements are constructed (initialized)**
- **The last “capacity - size” elements are uninitialized**
- push_back / emplace_back use the uninitialized elements until they are full; then, they **multiply the vector capacity by 2**.

# emplace_back / push_back Average Time Complexity

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

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

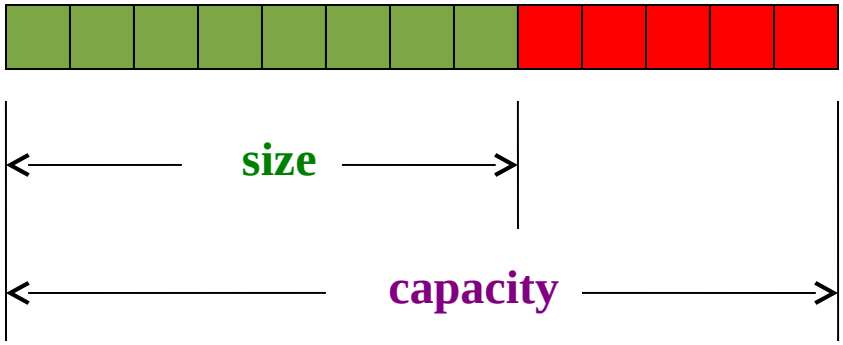
O(n) + **1**+**2**+**4**+**8**+**16**+…+**n** =

O(n)

On average an each insertion cost O(1)

# size and capacity methods

*(see folder 1)*




- `uint size() const;`
- `uint capacity() const;`
- `void reserve(uint new_capacity);`
  `// ensure that the capacity is`
  `// at least "new_capacity".`

# vector<T> v

# v.shrink_to_fit() // c++11

# 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**

# vectors: 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 elements.
  - Two accessors (with and without range check) vs. a single accessor

# deque

- More efficient insertion at start and middle;
- Less efficient deallocation.
- How do we know? - performance tests:
- https://www.codeproject.com/Articles/5425/An-In-Depth-Study-of-the-STL-Deque-Container
- Implementation – non contiguous blocks:
  https://stackoverflow.com/a/6292437/827927

# *basic_strings*

- The well-known **string** is just a typedef for **basic_string<char>.**
- **basic_string** can be used with any char-like type (folder 1)**.**

| | String operations (e.g. substr, replace, stol) | Non-trivial classes (e.g. with vptr, heap usage) |
|---|---|---|
| **vector** | No | Yes |
| **basic_ string** | Yes | No |

# STL: Associative Containers

# Associative Containers

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

(Typical) Implementation:

- red-black binary trees
- hash-table

# Associative Containers

**Ordered**: Objects are ordered by "<".
Insertion, deletion, find: O(log n).

**set**: Unique keys.

**map**: Associate unique keys to values.

**multiset**: Allows multiple keys.

**multimap**: Associate keys to multiple values.

**Unordered**: Insertion, deletion, find: O(1).

**unordered_set**: Unique keys.

**unordered_map**: Associate keys to values.

**unordered_multiset**: Allows multiple keys.

**unordered_multimap**: Associate keys to multiple values.

# Sorted Associative Containers & Order

- Sorted associative containers assume that their elements are *LessThanComparable*.
- They use operator< as default order.
- We can control order using our own comparison function.
- We need to use a **functor**.

# *Functor*

A functor in C++ is an object with an **operator()**. Examples:

- Pointer to function (like in C);
- A class that implements **`operator();`**
- Lambda [] expressions.

# Functor in the STL

```
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;
```

# Why should we use classes as functors?

So that we get the “power” of classes:

- Inheritance.
- Parameterize our functions in run time. (folder 2).
- Accumulate information.

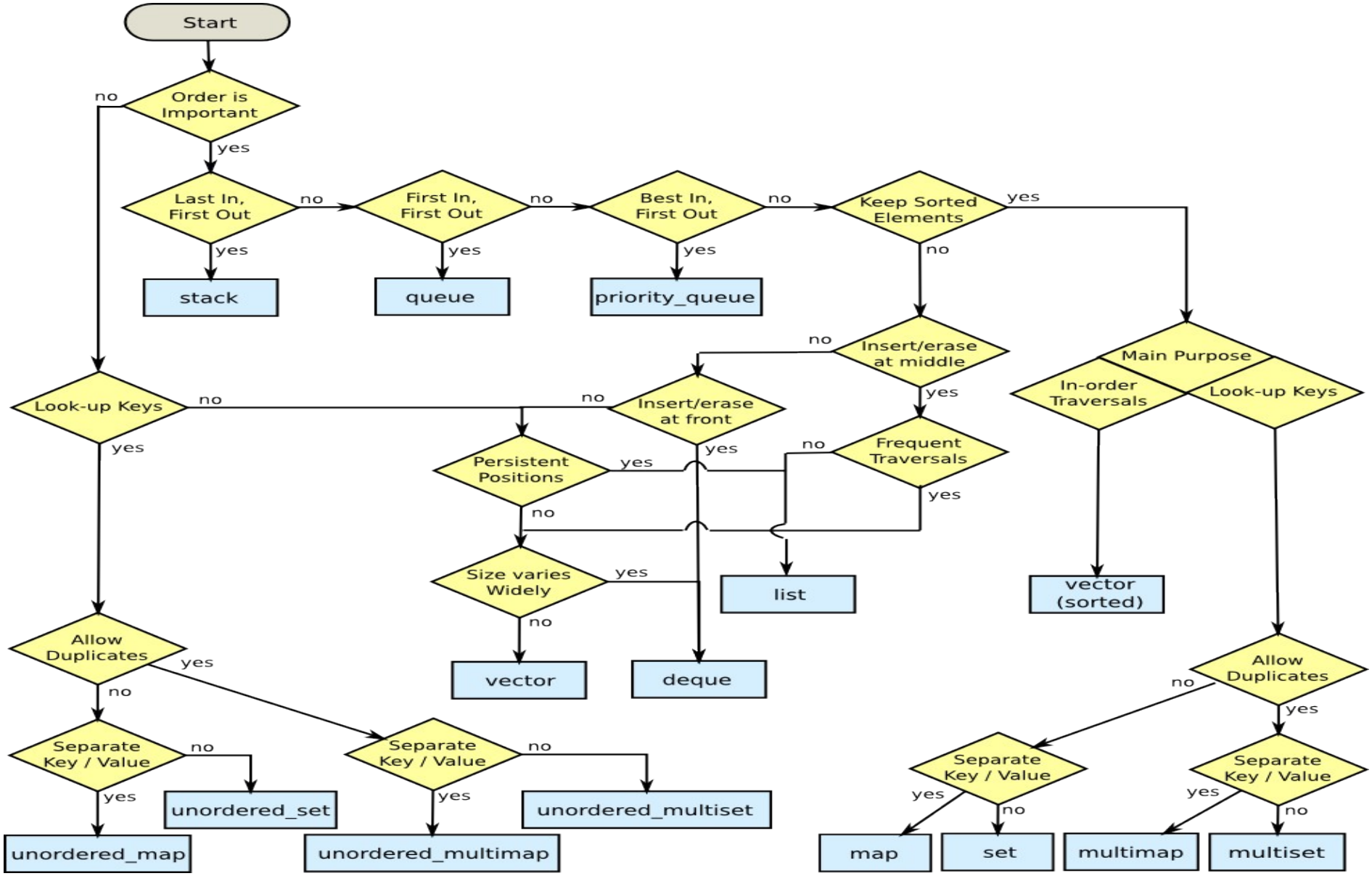
# Container Adaptors

Take any sequential container;

return a container with a given interface:

- **stack**: last in – first out;
- **queue**: first in – first out;
- **priority_queue**: best in – first out.

# How to choose a container?




Mikael Persson https://stackoverflow.com/a/22671607/827927