The C++ Standard Template Library (STL)

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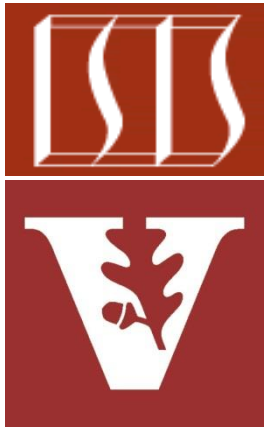

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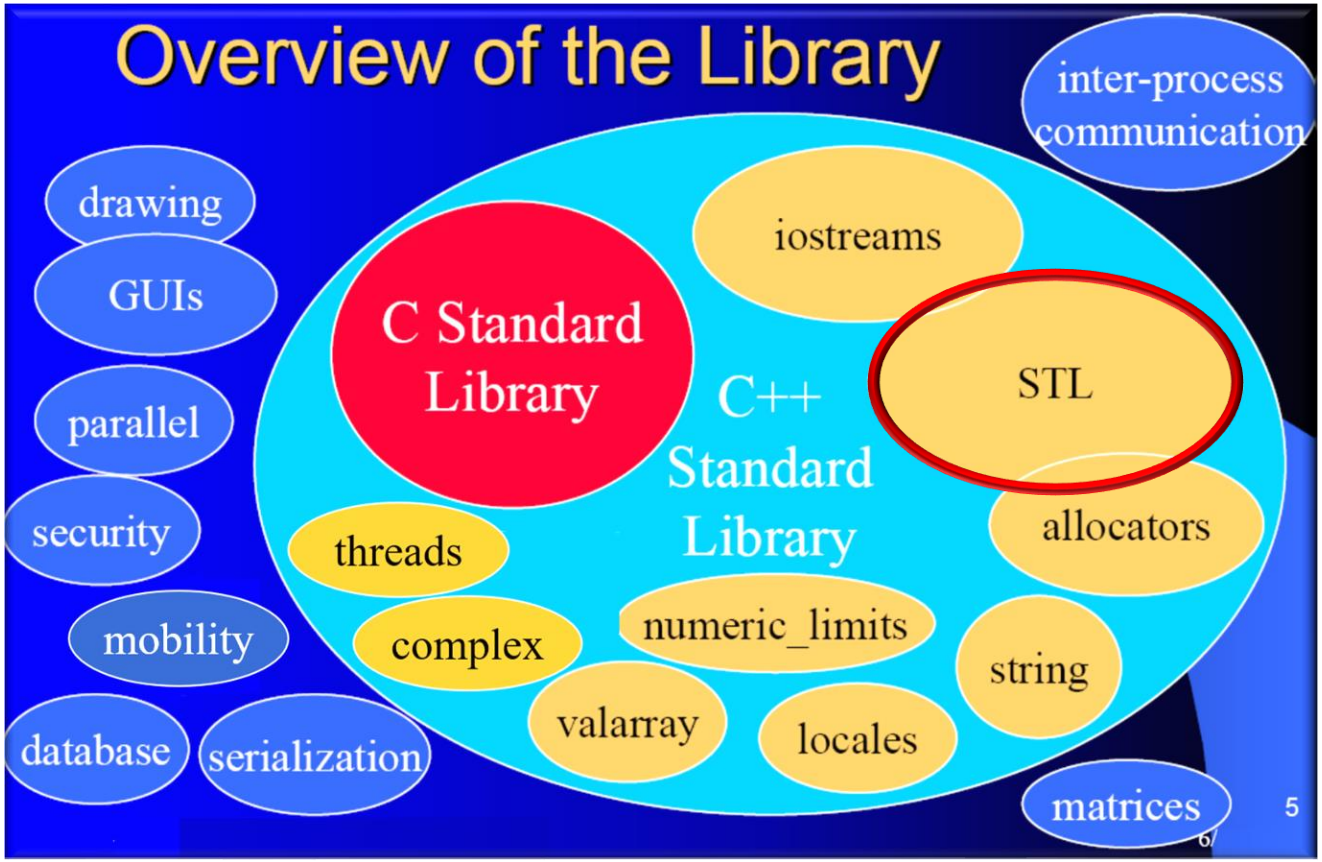
The C++ Standard Template Library: Presentation Outline

- What is STL?
- Generic programming: Why use STL?
- Overview of STL concepts & features
  - *e.g., helper class & function templates, containers, iterators, generic algorithms, function objects, adapters*
- A complete STL example
- References for more information on STL

What is the C++ Standard Template Library (STL)?

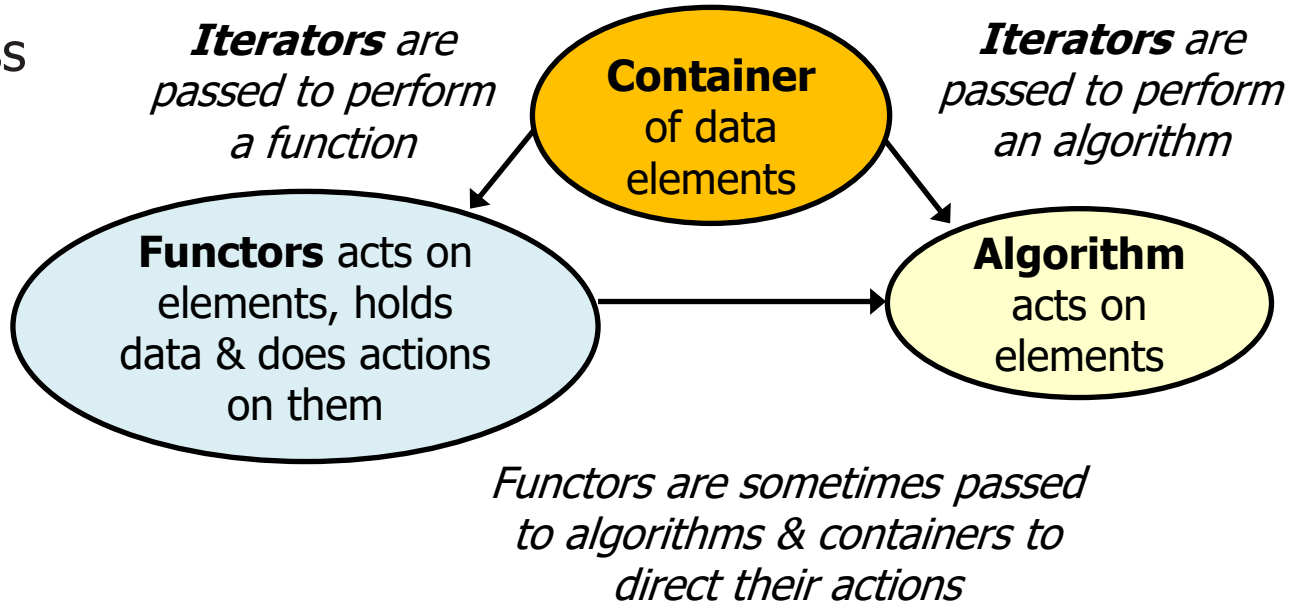
STL is a subset of the Standard C++ library that provides a set of well-structured **generic** *C++ components that work together in a* **seamless** *way*



See en.wikipedia.org/wiki/Standard_Template_Library

What is the C++ Standard Template Library (STL)?

- A collection of composable class & function templates
  - Helper class & function templates: operators, pair
  - Container & iterator class templates
  - Generic algorithms that operate over *iterators*
  - Functors (function objects)
  - adapters



What is the C++ Standard Template Library (STL)?

- Enables ***generic programming*** in C++

See en.wikipedia.org/wiki/Generic_programming

What is the C++ Standard Template Library (STL)?

- Enables ***generic programming*** in C++
  - A programming paradigm in which algorithms are written in terms of *generic* types, which are instantiated when needed for *specific* types provided as parameters

```
template <typename InputIterator,
          typename T>
InputIterator find
  (InputIterator first,
   InputIterator last,
   const T& value) {
  while (first != last
         && *first != value)
    ++first;
  return first;
}
...
vector<int> v {1, 2, 3, 4};
auto i = find(v.begin(),
              v.end(),
              3);
```

What is the C++ Standard Template Library (STL)?

- Enables ***generic programming*** in C++
  - A programming paradigm in which algorithms are written in terms of *generic* types, which are instantiated when needed for *specific* types provided as parameters
  - Each generic algorithm can operate over *any iterator for which the necessary operations are provided*

```
template <typename InputIterator,
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InputIterator find
  (InputIterator first,
   InputIterator last,
   const T& value) {
  while (first != last
         && *first != value)
    ++first;
  return first;
}
...
int a[] = {1, 2, 3, 4};
int *e = a + sizeof(a)/sizeof(*a);
auto i = find(a, e, 3);
```

What is the C++ Standard Template Library (STL)?

- Enables ***generic programming*** in C++
  - A programming paradigm in which algorithms are written in terms of *generic* types, which are instantiated when needed for *specific* types provided as parameters
  - Each generic algorithm can operate over *any iterator for which the necessary operations are provided*
  - Extensible: can support new algorithms, containers, iterators

Generic Programming: Why Use STL?

- **Reuse: "write less, do more"**

Generic Programming: Why Use STL?

- **Reuse: "write less, do more"**
  - STL hides complex, tedious, & error-prone details
    - e.g., dynamic memory management, complex data structures & algorithms, many optimizations, etc.

Programmers can thus focus on the (business) problem at hand

Generic Programming: Why Use STL?

- **Reuse: "write less, do more"**
  - STL hides complex, tedious, & error-prone details
  - Ensures *type-safe* plug compatibility between STL components

```
vector<int> v{2, 4, 3, 5, 1};
list<int> l{5, 2, 1, 2, 3};

sort(v.begin(), v.end()); // Ok
sort(l.begin(), l.end()); // Error
```

C++ STL performs static type checking to enhance correctness & performance

Generic Programming: Why Use STL?

- **Flexibility**

Generic Programming: Why Use STL?

- **Flexibility**
  - Iterators decouple algorithms from containers

```
vector<int> v{1, 2, 3, 4, 5};
list<int> l{5, 4, 3, 2, 1};

auto vi = find(v.begin(),
               v.end(),
               5);

auto li = find(l.begin(),
               l.end(),
               5);
```

Generic Programming: Why Use STL?

- **Flexibility**
  - Iterators decouple algorithms from containers
  - Unanticipated combinations easily supported
    - e.g., via adapters

```
vector<int> v{1, 2, 3, 4, 5};
list<int> l{5, 4, 3, 2, 1};

template<typename T>
struct greater_than_5 {
  bool operator()(const T &i)
  { return i > 5; }
};

auto i = find_if(v.begin, v.end(),
                 greater_than_5<>());
auto vi = find_if(v.begin(), v.end(),
                  bind(greater<>, _1, 5));
auto li = find_if(l.begin(), l.end(),
                  not_fn(bind(greater<>, _1, 5));
```

Generic Programming: Why Use STL?

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Generic Programming: Why Use STL?

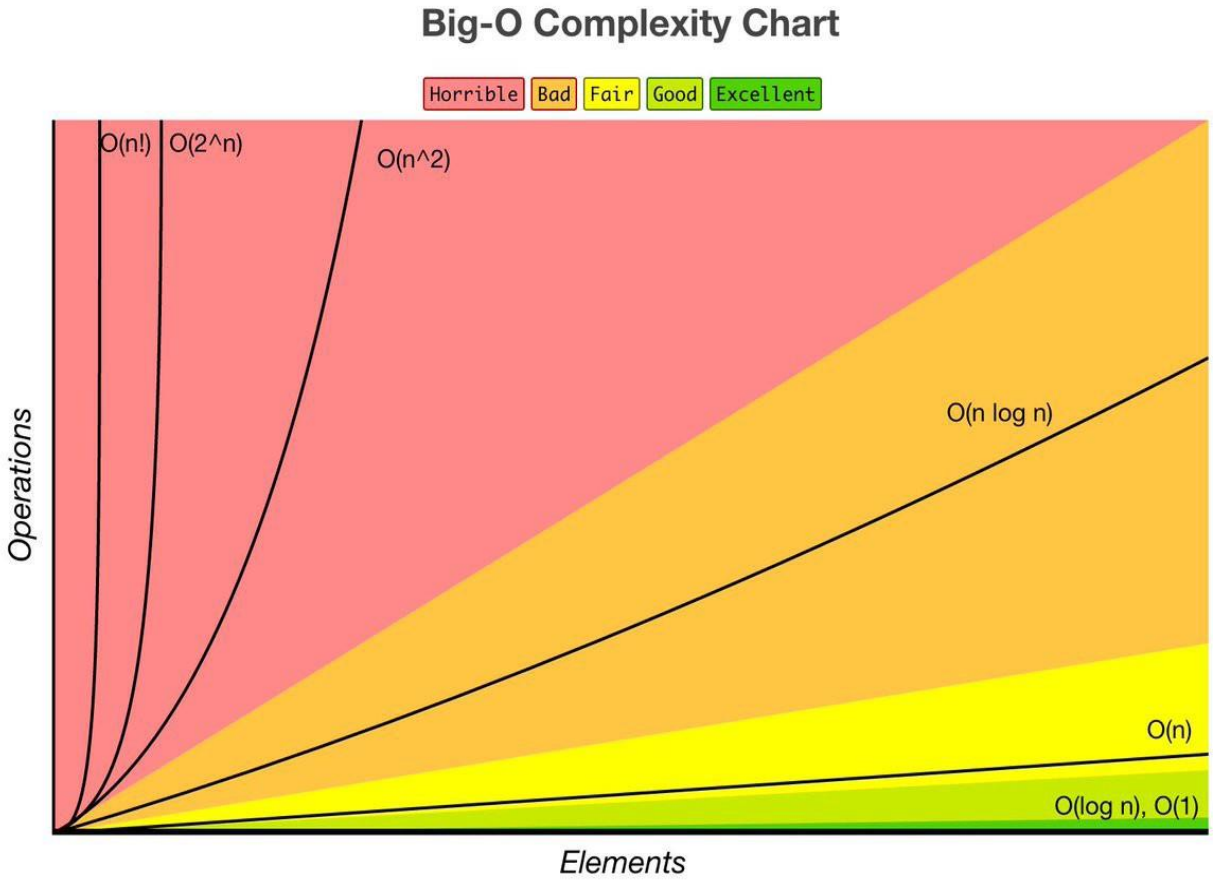
- **Efficiency**
  - Templates & inlining avoids virtual function overhead

```
vector<int> v{2, 4, 3, 5, 1};
list<int> l{5, 2, 1, 2, 3};

sort(v.begin(), v.end());
l.sort();
```

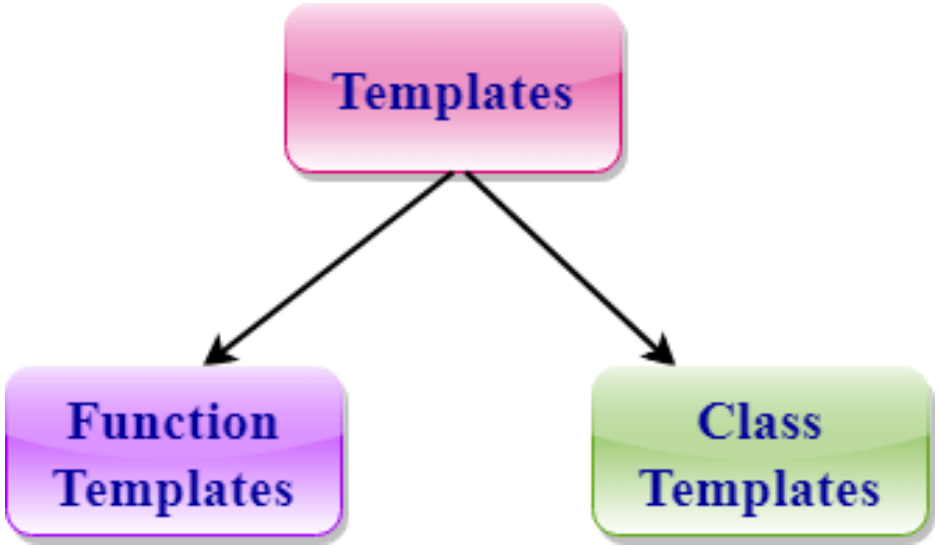
Generic Programming: Why Use STL?

- **Efficiency**
  - Templates & inlining avoids virtual function overhead
  - Strict attention to time complexity of algorithms



Generic Programming with C++ Function & Class Templates

- C++ STL makes heavy use of function templates & class templates



See en.wikipedia.org/wiki/Template_(C++)

Generic Programming with C++ Function & Class Templates

- C++ STL makes heavy use of function templates & class templates
  - **Function templates** are C++ functions that can operate on different data types without separate code for each of them

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Generic Programming with C++ Function & Class Templates

- C++ STL makes heavy use of function templates & class templates
  - **Function templates** are C++ functions that can operate on different data types without separate code for each of them
  - **Class templates** define a family of classes parameterized by type or values
    - If a set of functions have the same functionality for different data types, this becomes a good class template

```
template <typename T,
          typename Container =
            deque<T>>
class stack {
public:
  explicit stack(const Container&);
  bool empty() const;
  size_type size() const;
  value_type& top();
  const value_type& top() const;
  void push(const value_type& t);
  void pop();
private :
   Container container_ ;
   // …
};
```