Sequential Containers

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Game Plan

Recap
Overview of STL
Sequence Containers
std::vector
std::deque
Container Adapters
Announcements
Recap
You can define your own mini-types that bundle multiple variables together:

```c
struct point {
    int x;
    int y;
};
```

Useful for Assignment 1
struct point {
    int x;
    int y;
};

point p;
p.x = 12;
p.y = 15;
Overview of STL
“As mathematicians learned to lift theorems into their most general setting, so I wanted to lift algorithms and data structures”

— Alex Stepanov, inventor of the STL
Overview of STL

- Allocators
- Containers
- Iterators
- Algorithms
- Functors/Lambdas
- Adapters
Where we are going...

Here is a program that generates a vector with random entries, sorts it, and prints it, all in one go!

```cpp
const int kNumInts = 200;
std::vector<int> vec(kNumInts);
std::generate(vec.begin(), vec.end(), rand);
std::sort(vec.begin(), vec.end());
std::copy(vec.begin(), vec.end(),
    std::ostream_iterator<int>(cout, "\n"));
```
Sequence Containers
Sequence Containers

Provides access to sequences of elements.

Examples:

- `std::vector<T>`
- `std::list<T>`
- `std::deque<T>`
std::vector<T>
A vector represents a sequence of elements of any type.

You specify the type when using the vector:

```cpp
std::vector<int> vecInt; // vector of ints
std::vector<std::string> vecStr; // vector of string
std::vector<myStruct> vecStruct; // vector of myStructs
std::vector<std::vector<string>> vecOfVec; // vector of vector of string
```
### Summary of `std::vector<T>` vs Stanford Vector<T>

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<td>\texttt{v1 += v2;} \hspace{1cm} // We'll talk about this in another lecture...</td>
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Problem:

Write a program that reads a list of integers and finds the median.

Vector Median

(VecMedian.pro)
std::vector<T>

Some new stuff there:

```cpp
const int kNumInts = 5;

using vecsz_t = std::vector<int>::size_type;

std::sort(vec.begin(), vec.end());
```
Some new stuff there:

```cpp
const int kNumInts = 5;

using vecsz_t = std::vector<int>::size_type;

std::sort(vec.begin(), vec.end());
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This is a promise to the compiler that this variable won’t change.
Some new stuff there:

```cpp
const int kNumInts = 5;

using vecsz_t = std::vector<int>::size_type;

std::sort(vec.begin(), vec.end());
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This let’s us use `vecsz_t` as an alias/synonym for the type `std::vector<int>::size_type`;
Some new stuff there:

```cpp
const int kNumInts = 5;

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std::sort(vec.begin(), vec.end());
```

This takes a range of the vector and sorts it
Some Differences - `std::vector<T>` vs Stanford Vector<T>

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**Why these differences?**
Why the Differences?

Why doesn’t std::vector bounds check by default?

Hint: Remember our discussion of the philosophy of C++

If you write your program correctly, bounds checking will just slow your code down.
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Why these differences?
Why is `push_front` slow?

Requires shifting over of the other elements in the vector down one by one (bad).

**Illustration:** Say we have a small vector

```
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Why is \texttt{push\_front} slow?

Suppose \texttt{push\_front} existed and we used it.
Why is `push_front` slow?

Suppose `push_front` existed and we used it.

```cpp
vec.push_front(7);
```

```
    7
   /\      
  /  \     
 /    \    
3 1 4 1 5
```

0th index
Why is `push_front` slow?

Suppose `push_front` existed and we used it.

```
vec.push_front(7);
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Need to shift these elements up to make space in the 0th position.
Why is \texttt{push\_front} slow?

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![Diagram of vector with elements 7, 3, 1, 4, 1, 5]
Why is `push_front` slow?

Suppose `push_front` existed and we used it

```cpp
vec.push_front(7);
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Now we can insert the new element.
Why is `push_front` slow?

Suppose `push_front` existed and we used it

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0th index
Why is `push_front` slow?
Why is `push_front` slow?

Let’s get a sense of the difference:

Insertion Speed

`(InsertionSpeed.pro)`
Why is `push_front` slow?

The results:
Why is `push_front` slow?

A vector is the **prime** tool of choice in most applications!

- Fast
- Lightweight
- Intuitive

However, we just saw vectors only grow efficiently in **one direction**.

Sometimes it is useful to be able to `push_front` **quickly**!

C++ has a solution!
std::deque<T>
A deque (pronounced “deck”) is a double ended queue.

Can do everything a vector can do

and also...

Unlike a vector, it is possible (and fast) to push_front and pop_front.
We can see the efficiency of `push_front` with a `std::deque`
std::deque<T>

The results:
The results:

```cpp
std::deque<T>
```

Same scale as previous graph
The results:

std::deque<T>

There are the lines!
How does `std::deque<T>` work?

There is no single specific implementation of a deque, but one common one might look like this:
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There is no single specific implementation of a deque, but one common one might look like this:

```cpp
deq.push_front(7);
```
How does `std::deque<T>` work?

There is no single specific implementation of a deque, but one common one might look like this:

```cpp
std::deque<int> deq;
deq.push_front(7);
```
How does `std::deque<T>` work?

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```
std::deque<int> deq;
```

```cpp
deq.push_back(3);
```
How does `std::deque<T>` work?

There is no single specific implementation of a deque, but one common one might look like this:

```
    deq.push_back(3);
```

```
[NULL] [7] [3] [1] [NULL]
[4] [1] [5] [9]
```
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How does `std::deque<T>` work?

There is no single specific implementation of a deque, but one common one might look like this:

```cpp
deq.push_back(5);
```

```plaintext
<table>
<thead>
<tr>
<th>7</th>
<th>3</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>NULL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>5</td>
</tr>
</tbody>
</table>
```
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```
<table>
<thead>
<tr>
<th>7</th>
<th>3</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>6</td>
<td>5</td>
</tr>
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<td>4</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>
```
How does `std::deque<T>` work?

There is no single specific implementation of a deque, but one common one might look like this:

```
deq.push_back(5);
```

![Diagram of deque operations]

- `7 3 1`
- `2 6 5 3`
- `4 1 5 9`
How does `std::deque<T>` work?

There is no single specific implementation of a deque, but one common one might look like this:

```
std::vector<int> deq = {7, 3, 1, 4, 1, 5, 9};
deq.push_back(5);
```
How does `std::deque<T>` work?

There is no single specific implementation of a deque, but one common one might look like this:
Wait a minute...
Question

If deque can do everything a vector can do and also has a fast push_front...

Why use a vector at all?
Deques support fast `push_front` operations.

However, for other common operations like element access, vector will always outperform a deque.

Vector vs Deque

(VecDeqSpeed.pro)
Downsides of `std::deque<T>`

The results:
“vector is the type of sequence that should be used by default... deque is the data structure of choice when most insertions and deletions take place at the beginning or at the end of the sequence.”

— C++ ISO Standard (section 23.1.1.2)
Questions
Container Adapters
Container Adapters

Recall stacks and queues:
Container Adapters

Recall stacks and queues:
Container Adapters

Recall stacks and queues:

stack

<table>
<thead>
<tr>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
</tr>
<tr>
<td>41</td>
</tr>
<tr>
<td>12</td>
</tr>
</tbody>
</table>
Container Adapters

Recall stacks and queues:

```
stack
13
41
12
```

pop
Container Adapters

Recall stacks and queues:
Recall stacks and queues:

container adapters

stack

queue

9

16

11
Container Adapters

Recall stacks and queues:

- Stack:
  - 13
  - 41
  - 12

- Queue:
  - 9
  - 16
  - 11
  - 5

- `push_back`
Recall stacks and queues:

**Container Adapters**

- **Stack:**
  - 13
  - 41
  - 12

- **Queue:**
  - 9
  - 16
  - 11
  - 5
  - back
Recall stacks and queues:

Stack:
- 13
- 41
- 12

Queue:
- 16
- 11
- 5

Operations:
- pop_front
- back
Container Adapters

Recall stacks and queues:

- Stack:
  - 13
  - 41
  - 12

- Queue:
  - 16
  - 11
  - 5
  - back
How can we implement stack and queue using the containers we have?

**Stack:**

Just limit the functionality of a vector/deque to only allow `push_back` and `pop_back`.

**Queue:**

Just limit the functionality of a deque to only allow `push_back` and `pop_front`.

Plus only allow access to **top** element.
Container Adapters

For this reason, stacks and queues are known as container adapters.

std::stack
Defined in header `<stack>`

```cpp
template<
    class T,
    class Container = std::vector<T>
> class stack;
```

The `std::stack` class is a container adapter that gives the programmer the functionality of a stack - specifically, a FILO (first-in, last-out) data structure.

The class template acts as a wrapper to the underlying container - only a specific set of functions is provided. The stack pushes and pops the element from the back of the underlying container, known as the top of the stack.

**Template parameters**

- **T** - The type of the stored elements. The behavior is undefined if T is not the same type as `Container::value_type`. (Since C++11)
- **Container** - The type of the underlying container to use to store the elements. The container must satisfy the requirements of `SequenceContainer`. Additionally, it must provide the following functions with the usual semantics:
  - `back()`
  - `push_back()`
  - `pop_back()`

The standard containers `std::vector`, `std::deque` and `std::list` satisfy these requirements.

---

std::queue
Defined in header `<queue>`

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    class T,
    class Container = std::deque<T>
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The `std::queue` class is a container adapter that gives the programmer the functionality of a queue - specifically, a FIFO (first-in, first-out) data structure.

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Next Time

Associative Containers and Iterators