# Sequence Containers

Tell us a bad dad joke (optional).

CS 106L Winter 2020 Avery Wang and Anna Zeng

# Sequence Containers

Bad Dad Joke of the Day:

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# Sequence Containers

Bad Dad Joke of the Day:

- What's another name for oceans?
- Sea++!

Creds: James

# Game Plan

- Finishing Up C++ Types
- Survey Results!
- Overview of STL
- Sequence Containers
- Container Adaptors

# C++ Types (cont.)

# Streams Aside: When do I use...

...cin and cout?

...a filestream (fstream)?

...a stringstream?

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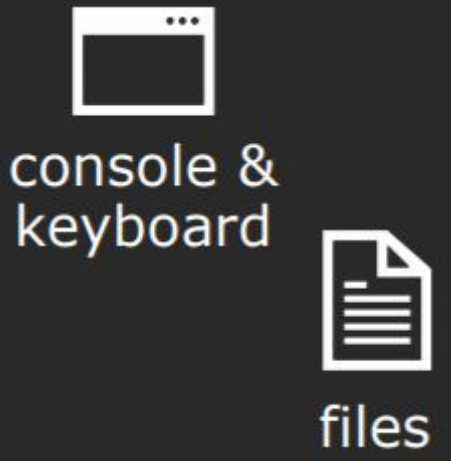

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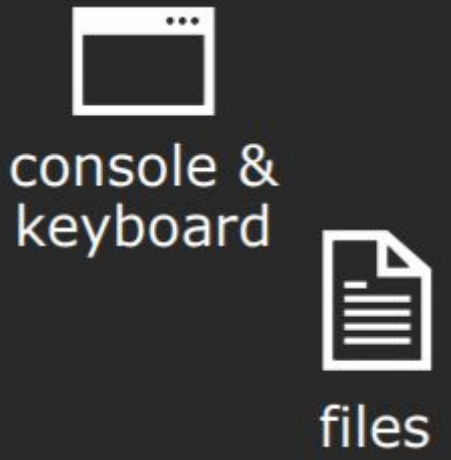


??

# stringstream vs. string

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When should I use a stringstream?

1. Processing strings
   - Simplify “/./a/b/..” to “/a”
2. Formatting input/output
   - uppercase, hex, and other stream manipulators
3. Parsing different types
   - stringToInteger() from previous lectures

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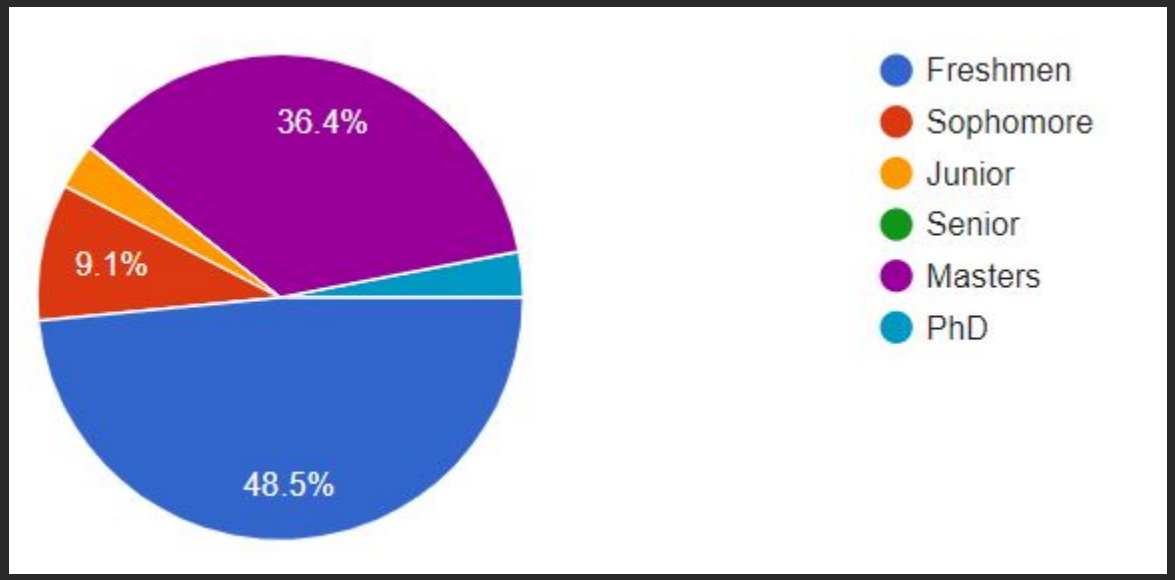
If you’re just concatenating strings, str.append() is faster than using a stringstream!

# Survey Results!


36.4%
9.1%
48.5%
Freshmen
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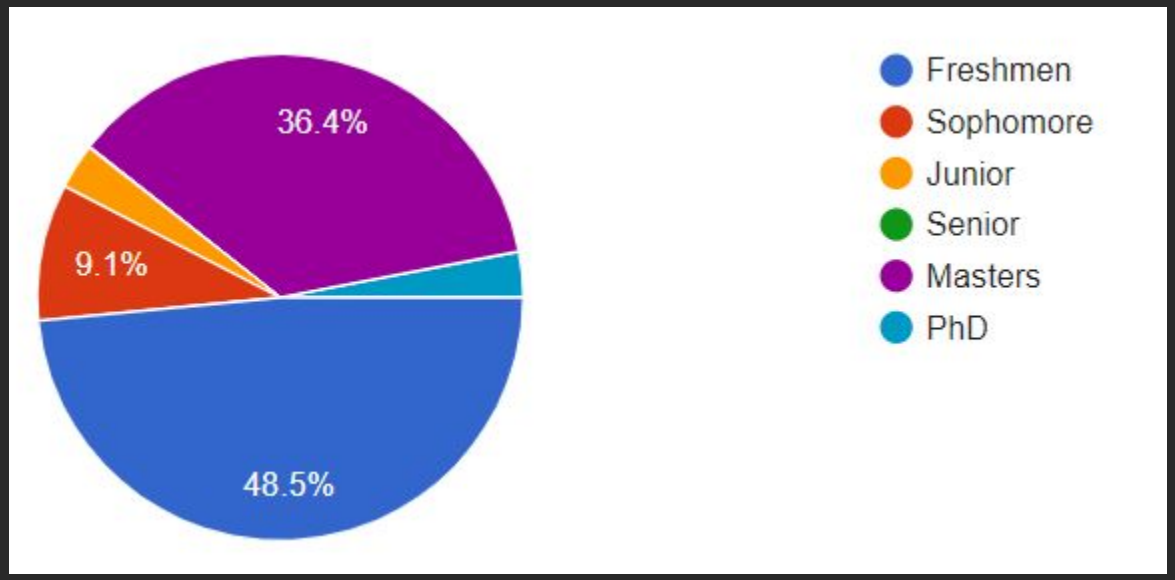
PhD

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- Aero/Astro
- Electrical Engineering
- Mechanical Engineering
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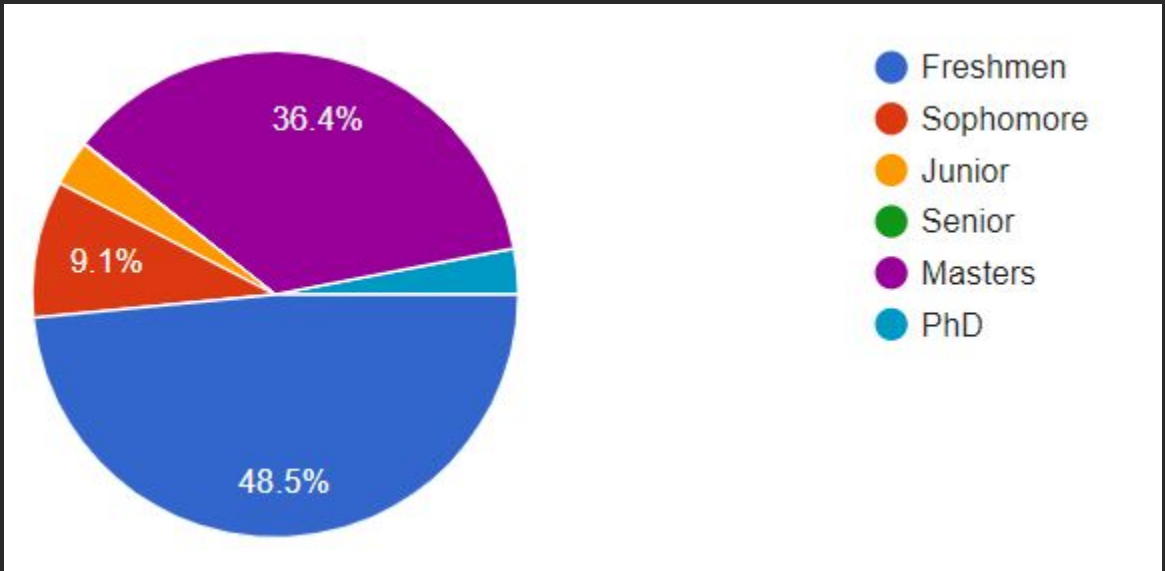
- And more!




Why you're here:

- Industry usages
- C++ practice
- Supplement CS 106B
- Personal projects

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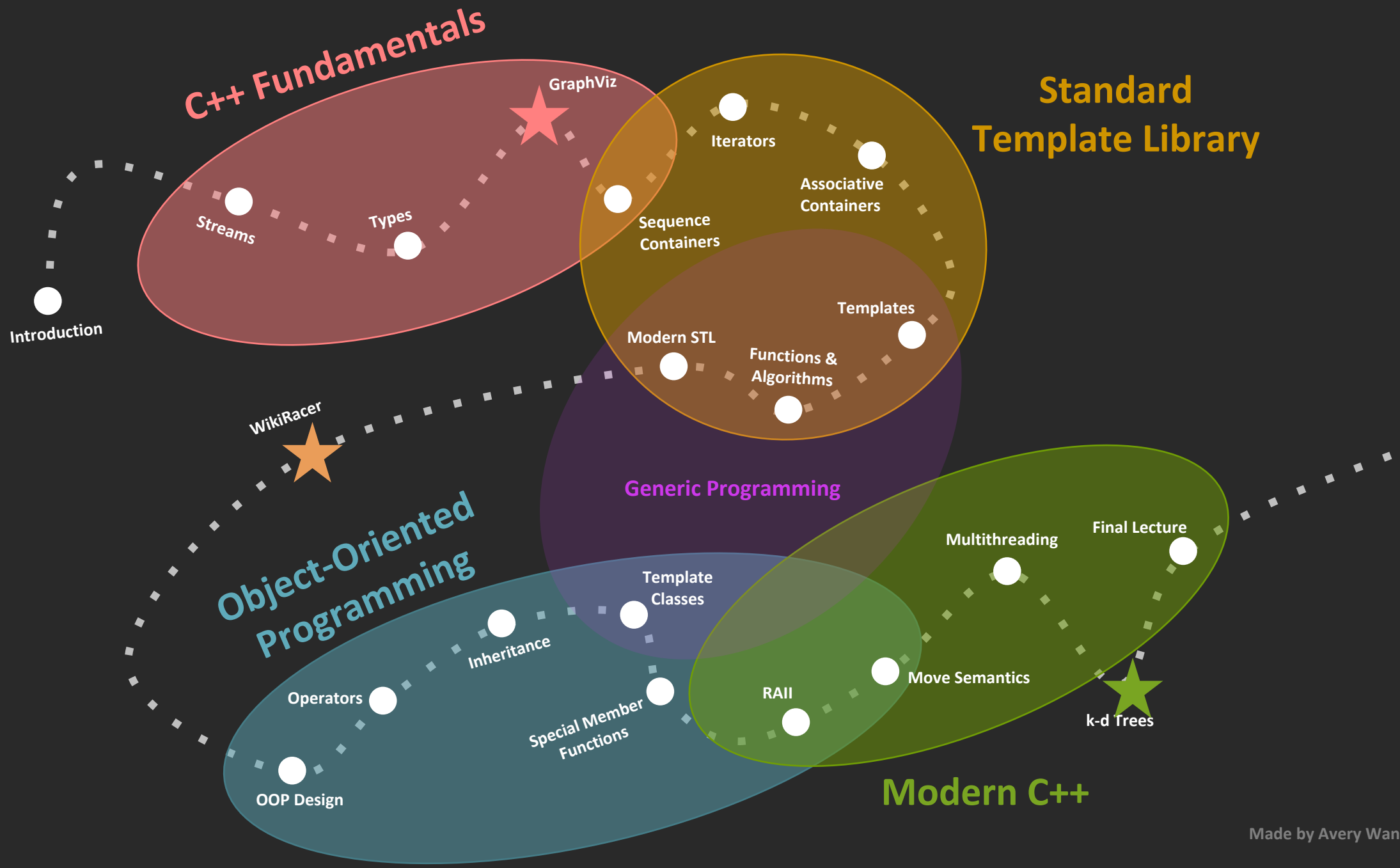
# The Standard Template Library (STL)




Made by Avery Wang

# 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

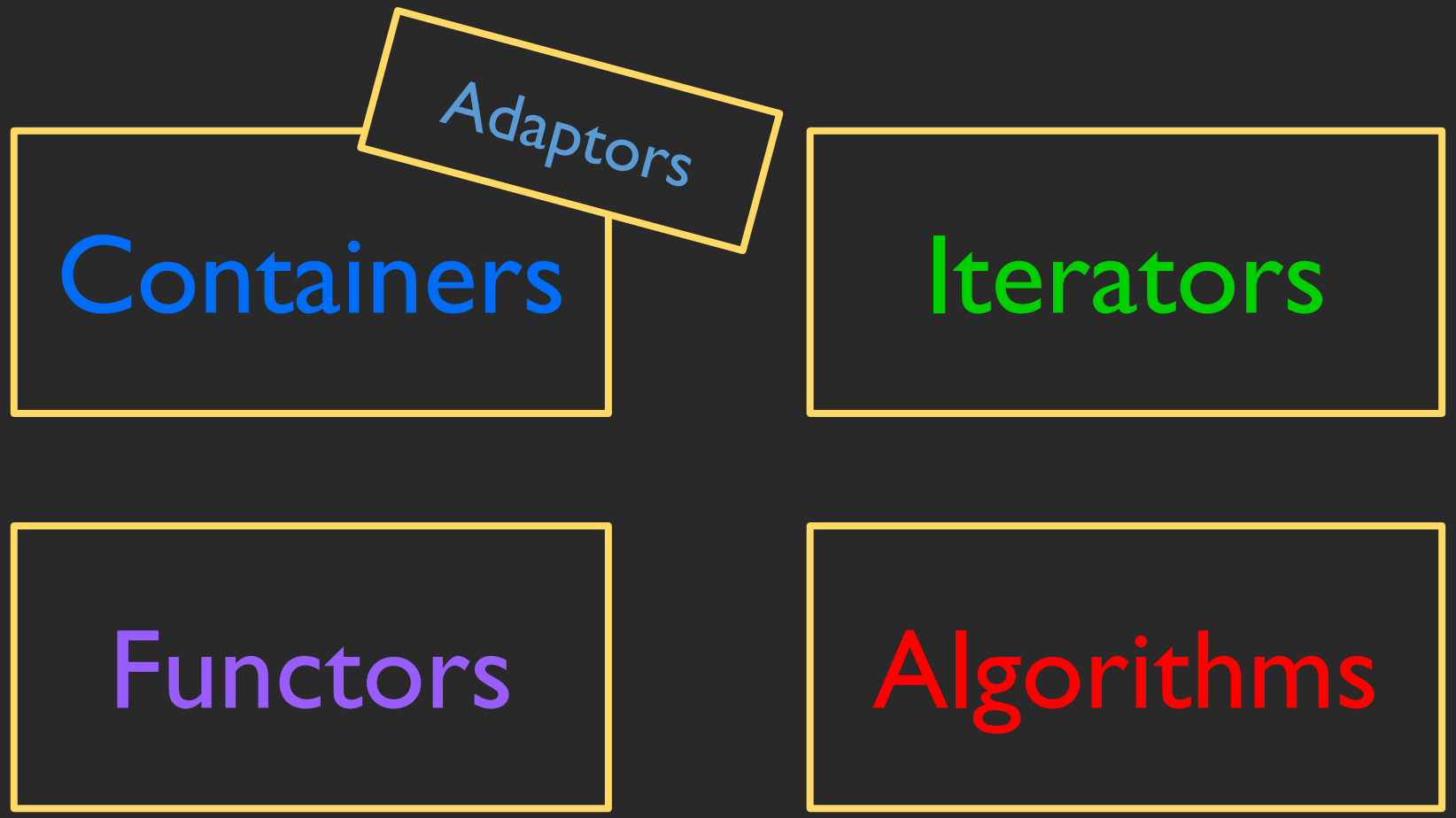
Containers

Iterators

Functors

Algorithms

# Overview of STL



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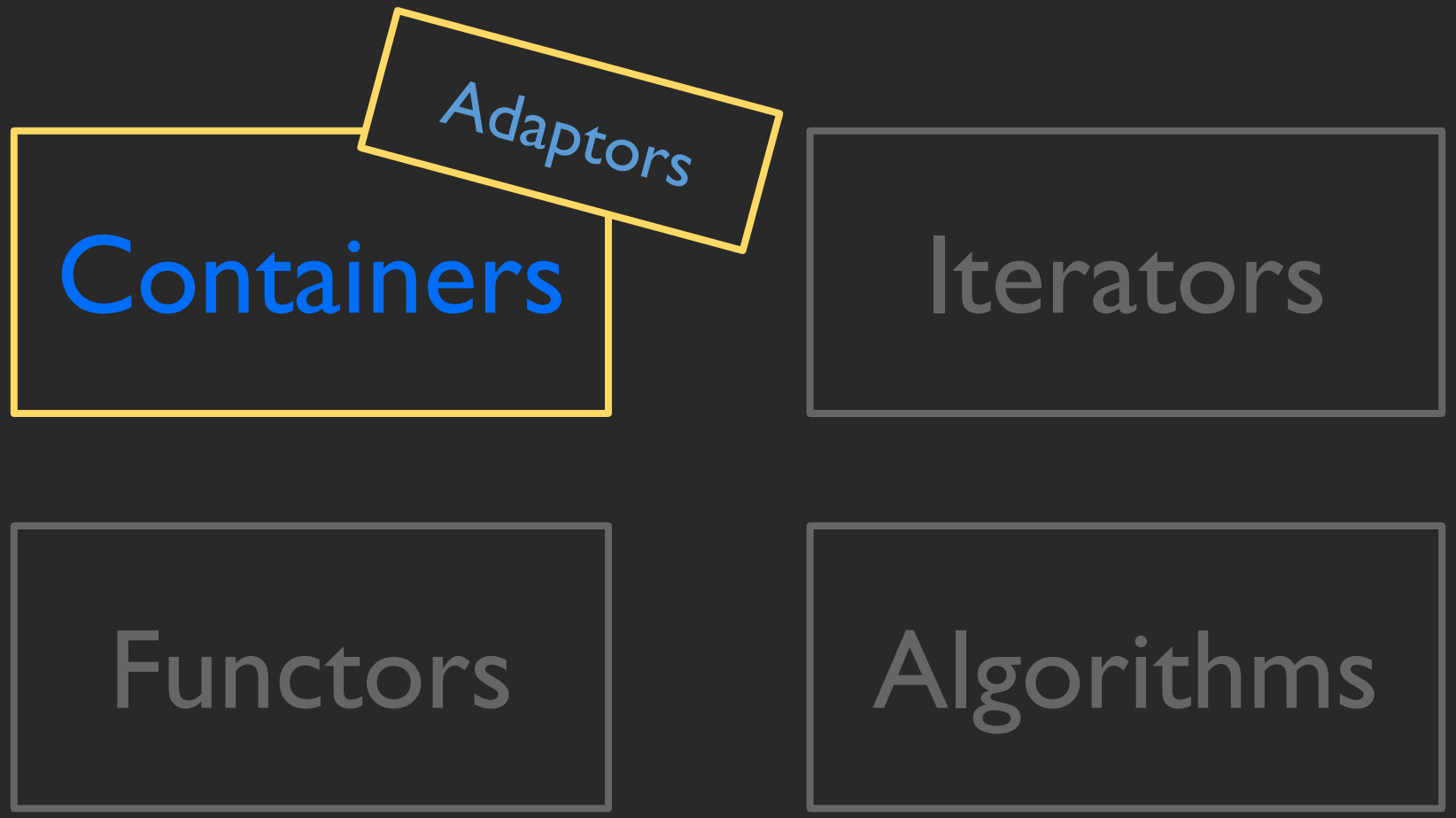

# Sequence Containers

# Sequence Containers

Provides access to sequences of elements.

Includes:

- `std::vector<T>`
- `std::deque<T>`
- `std::list<T>`
- `std::array<T>`
- `std::forward_list<T>`

```
std::vector<T>
```

# std::vector<T>

A vector represents a sequence of elements of any type.

You specify the type when using the vector:

```
std::vector<int> vecInt;            // vector of ints
std::vector<string> vecStr;         // vector of string
std::vector<myStruct> vecStruct; // vector of myStructs
std::vector<std::vector<string>> vecOfVec; // vector of
                                           vector<string>
```

# Stanford vs. STL: Part 1

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```
/*      Stanford C++ Version      */
Vector<int> v = { 1, 3, 7 };


v += 271;

cout << v[0] << endl;
cout << v[v.size() - 1] << endl;

Vector<int> first = v.subList(0, 2);
Vector<int> last  = v.subList(2);

v.remove(0);
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v.erase(v.begin());   // or v.pop_back()
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```
/*      Stanford C++ Version          */
Vector<string> v = { "A", "B", "C" };

/* Counting for loop. */
for (int i = 0; i < v.size(); i++) {
    cout << v[i] << endl;
}

/* Range-based for loop. */
for (string elem: v) {
    cout << elem << endl;
}
```

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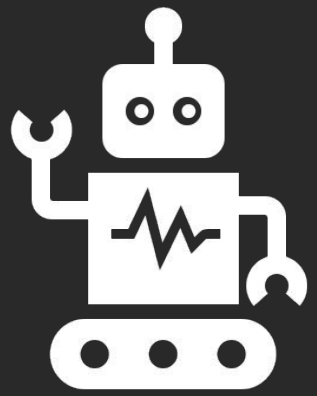

# Example

## Standard C++ Vector in (Basic) Action

# Why the Difference?

Why doesn't `std::vector` bounds check by default?

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

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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.

Play around with the `std::vector`!

http://www.cplusplus.com/reference/vector/vector/

# Summary of Stanford `Vector<T>` vs `std::vector<T>`

| What you want to do | Stanford Vector<int> | std::vector<int> |
|---|---|---|
| Create an empty vector | `Vector<int> v;` | `vector<int> v;` |
| Create a vector with n copies of zero | `Vector<int> v(n);` | `vector<int> v(n);` |
| Create a vector with n copies of a value k | `Vector<int> v(n, k);` | `vector<int> v(n, k);` |
| Add k to the end of the vector | `v.add(k);` | `v.push_back(k);` |
| Clear vector | `v.clear();` | `v.clear();` |
| Get the element at index i<br>(* Verify that i is in bounds!) | `int k = v.get(i);`<br>`int k = v[i];` | `int k = v.at(i);`<br>`int k = v[i];` (*) |
| Check if the vector is empty | `if (v.isEmpty()) ...` | `if (v.empty()) ...` |
| Replace the element at index i<br>(* Verify that i is in bounds!) | `v.get(i) = k;`<br>`v[i] = k;` | `v.at(i) = k;`<br>`v[i] = k;` (*) |

STL特殊之处：用.at()越界会报警；用[]越界不会报警

# One Important Similarity

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| Clear v | | |
| Get the bound | | |
| Check | | |
| Replac in bou | | |

What happens if we try to add an element to the beginning of a vector?

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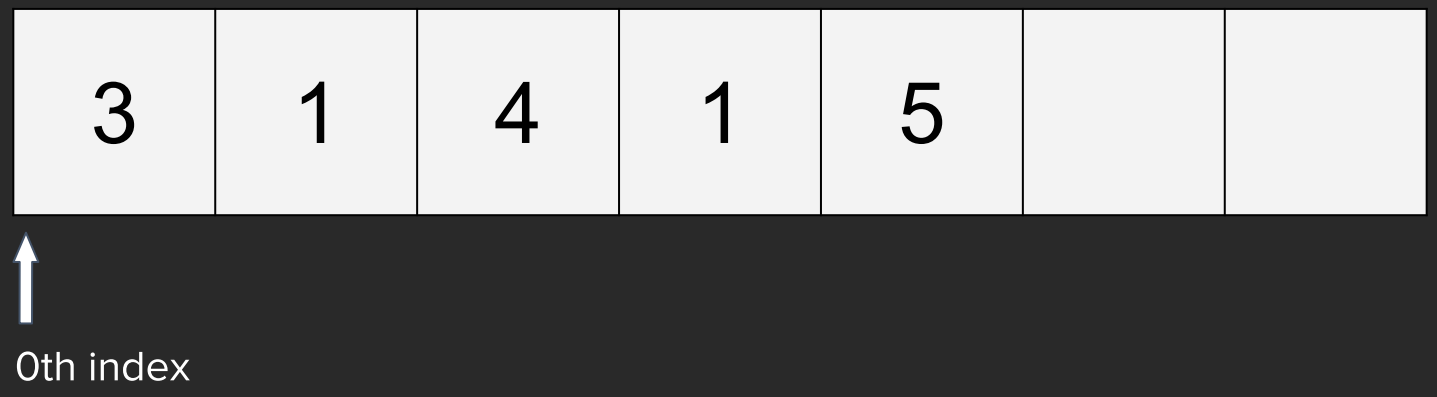
Suppose `push_front` existed and we used it.

Let's look at a small vector:



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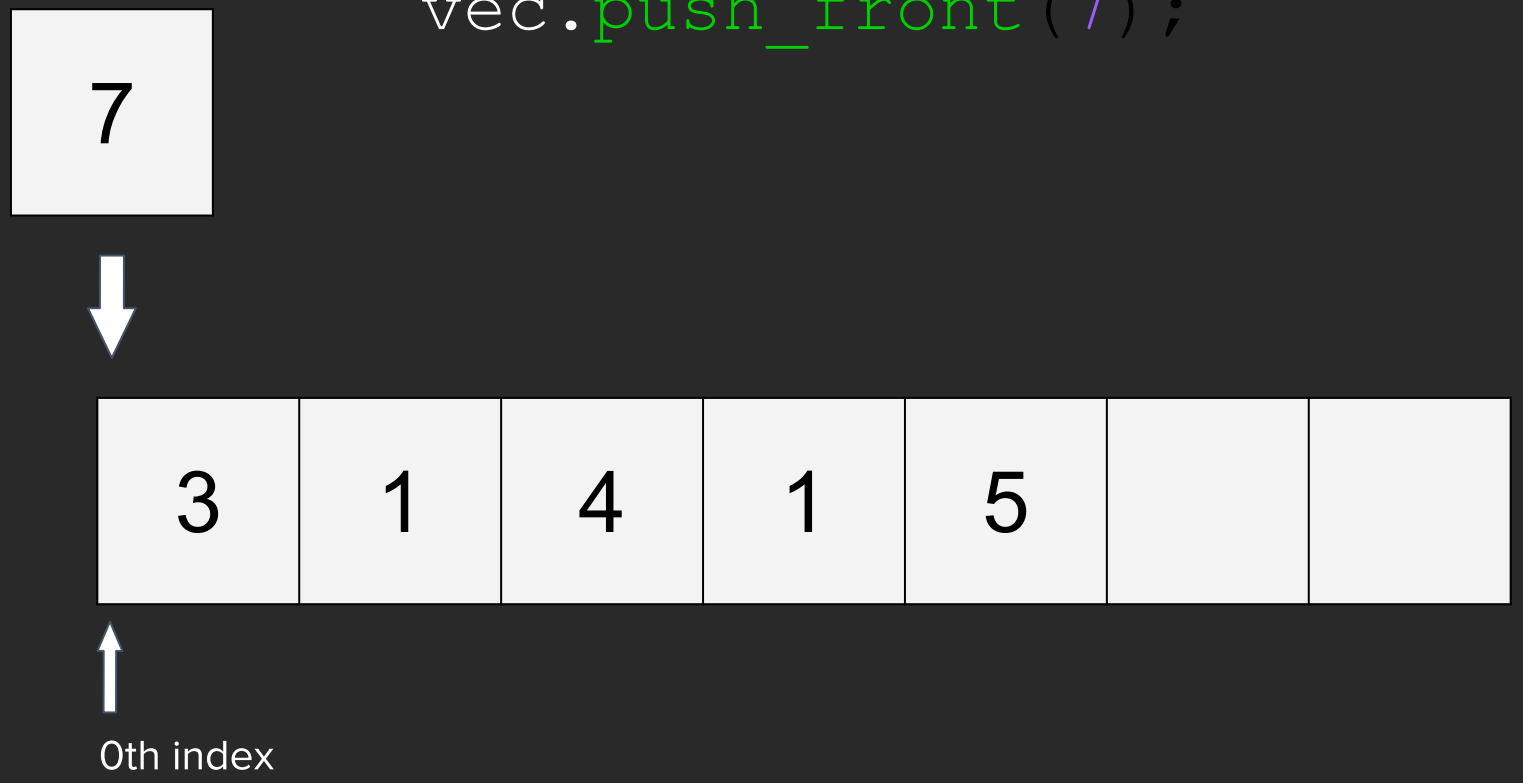

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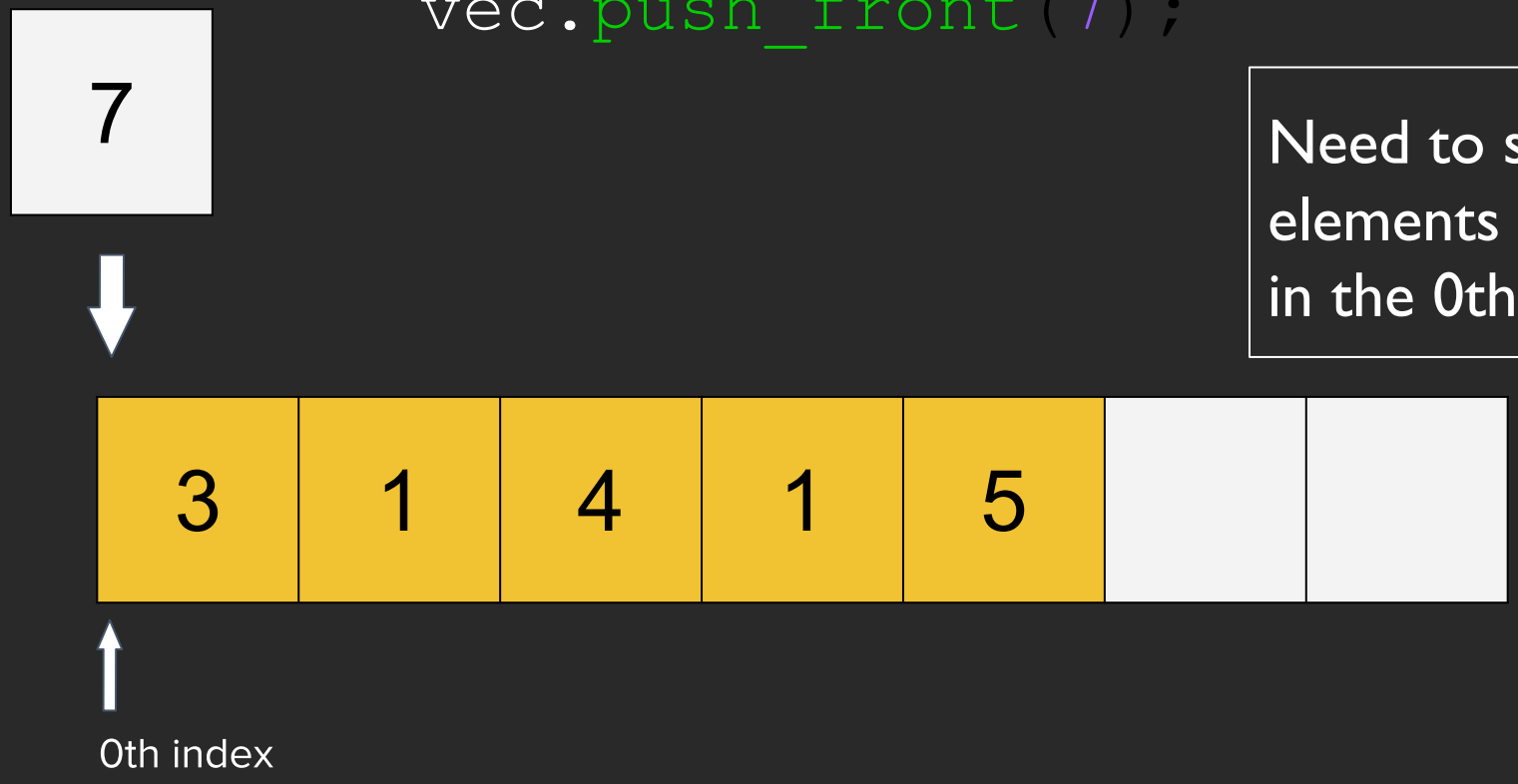


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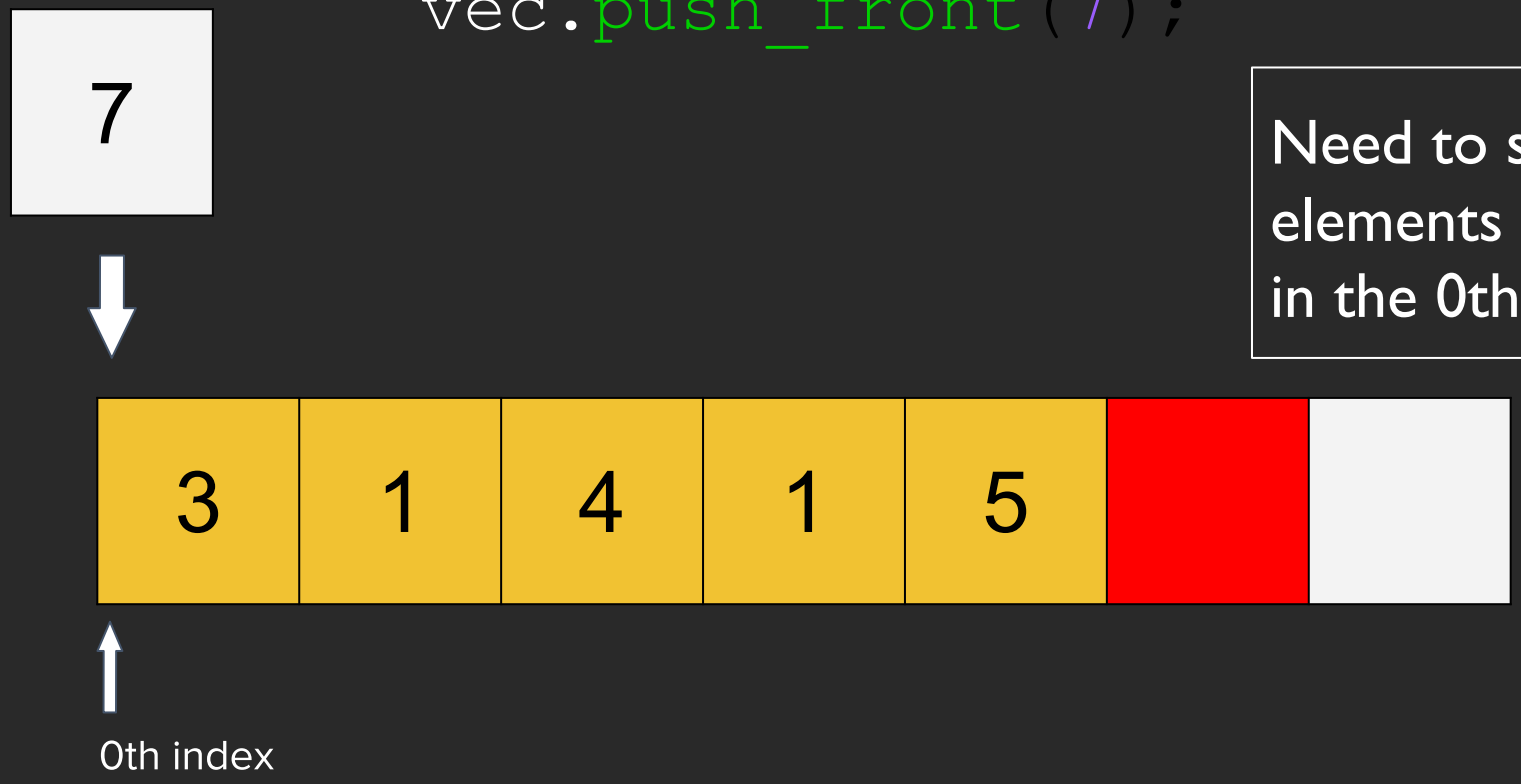


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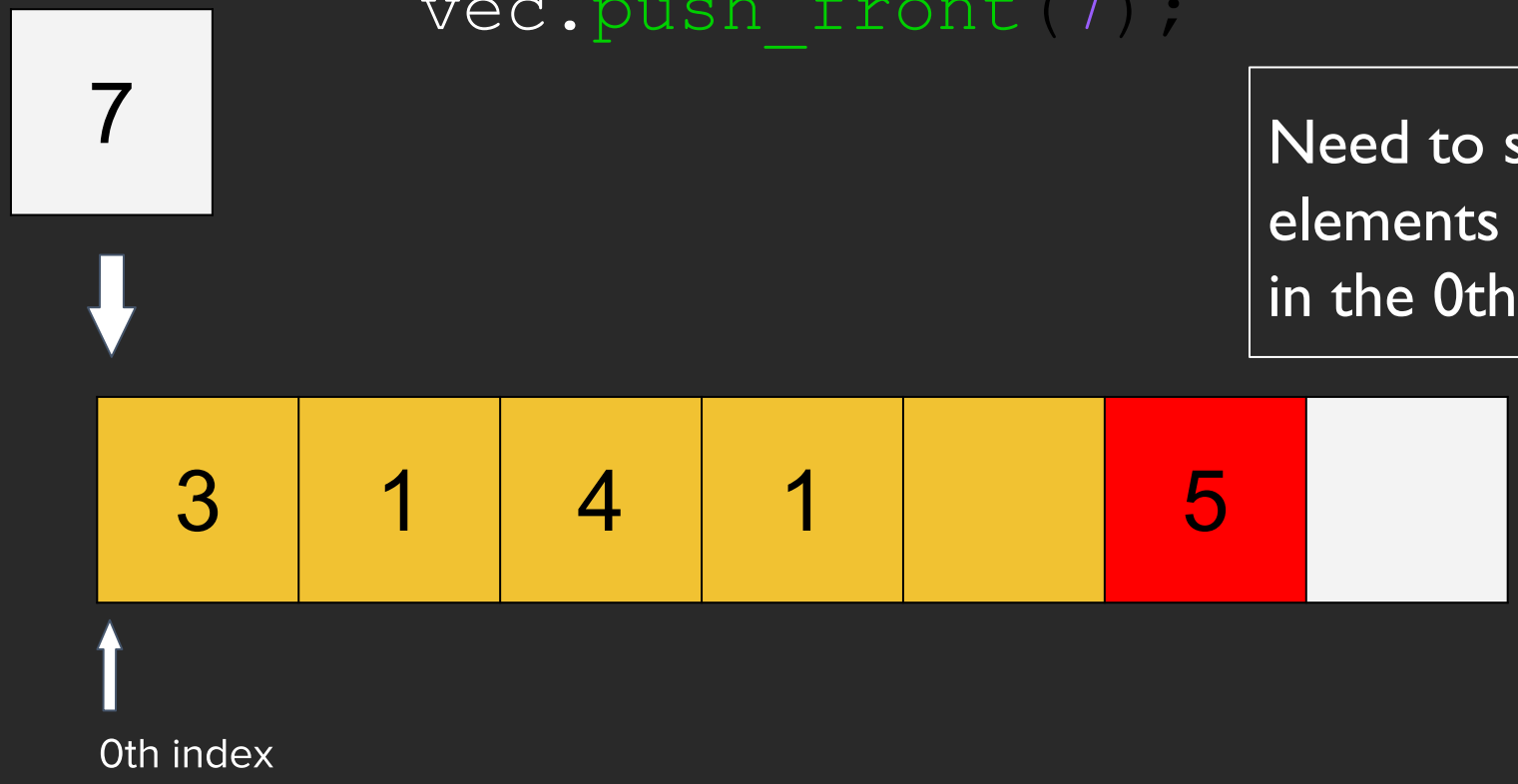


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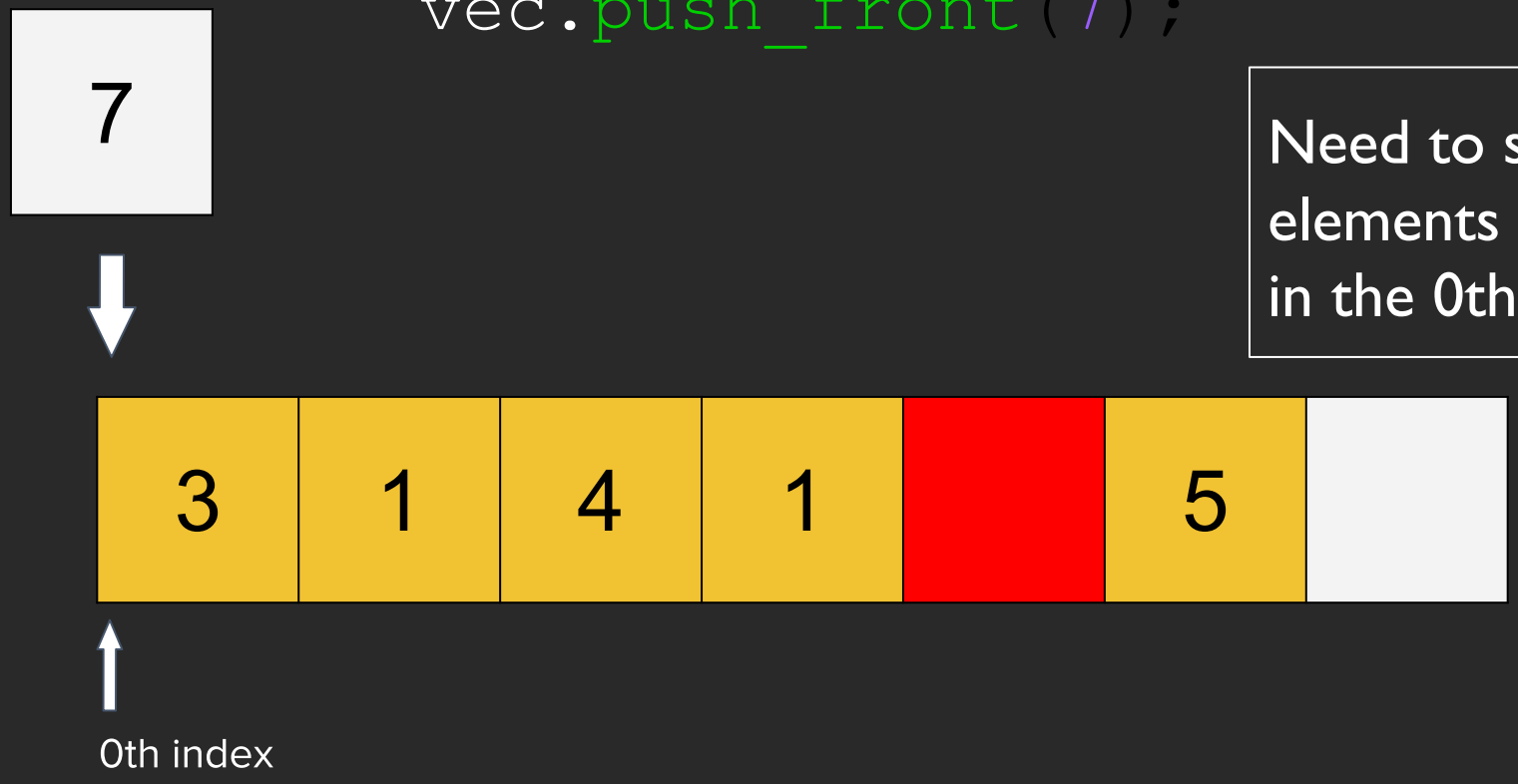


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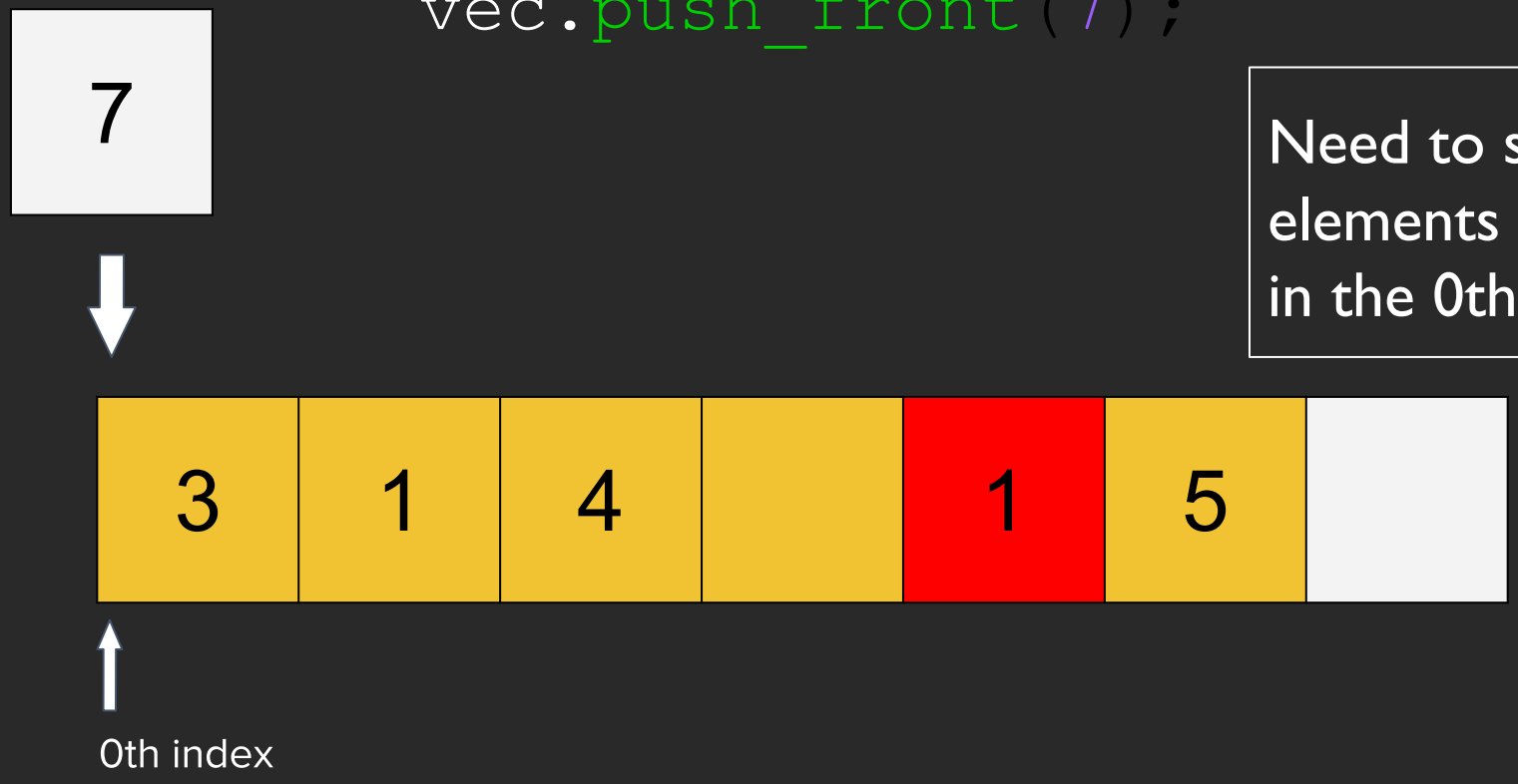


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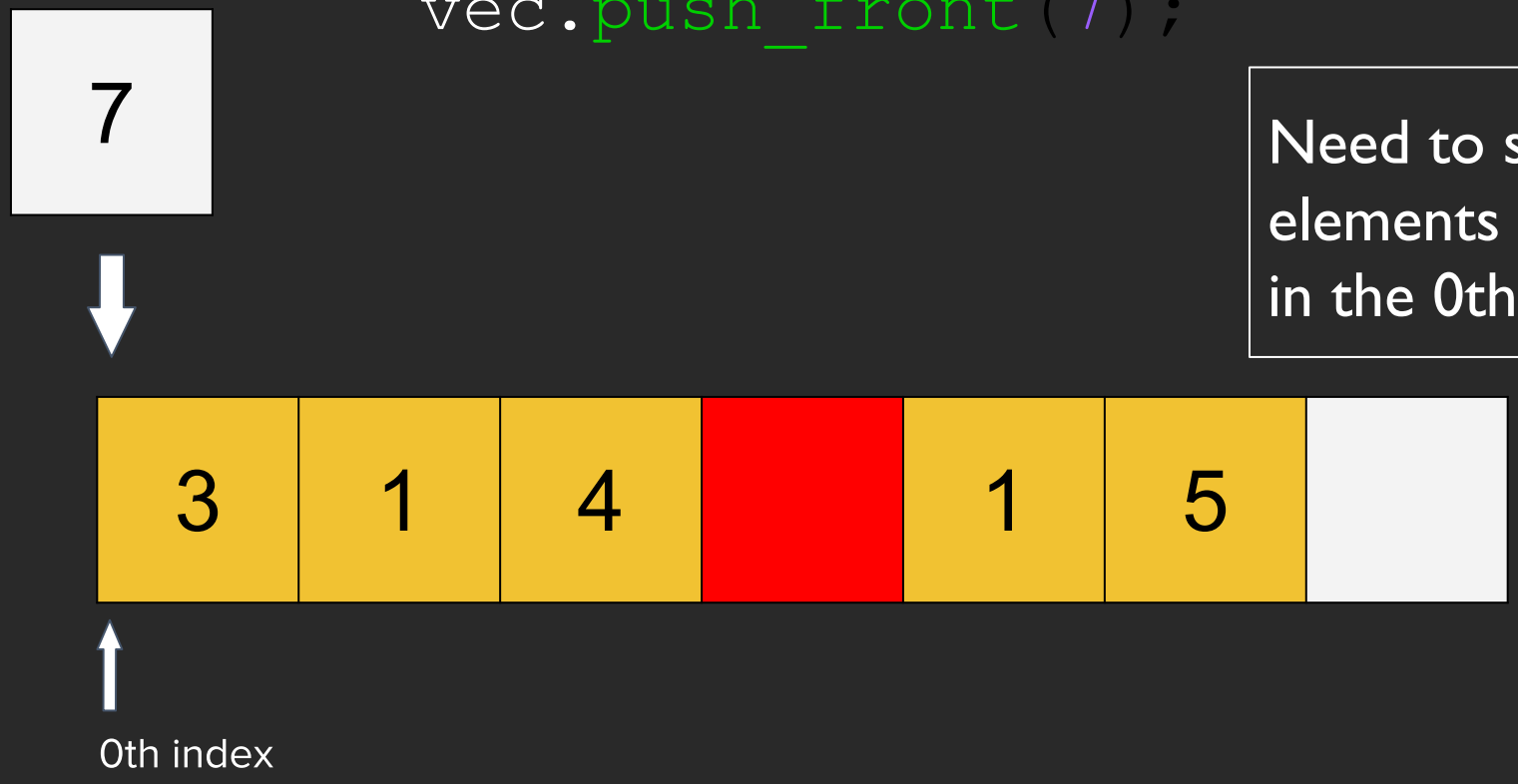


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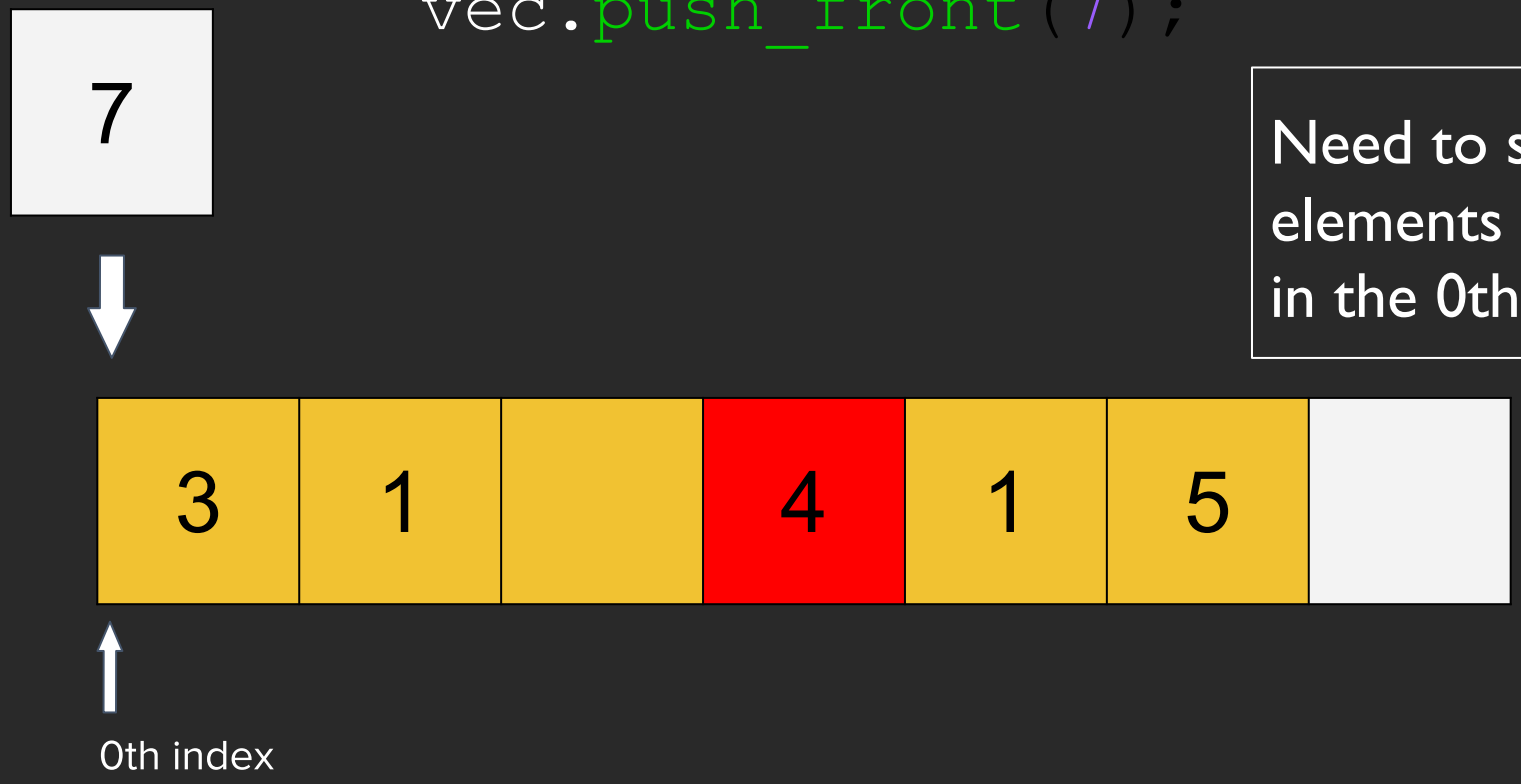


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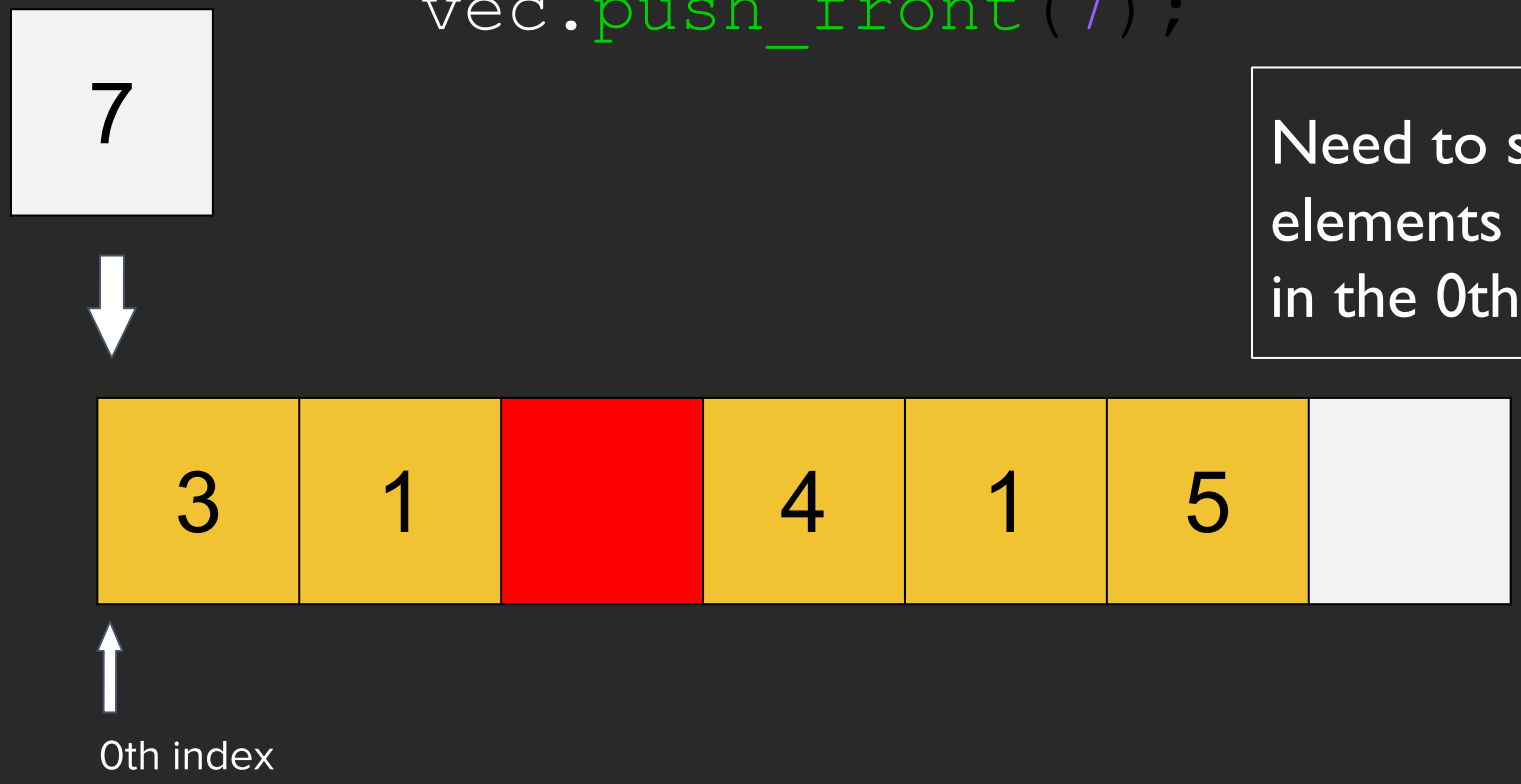


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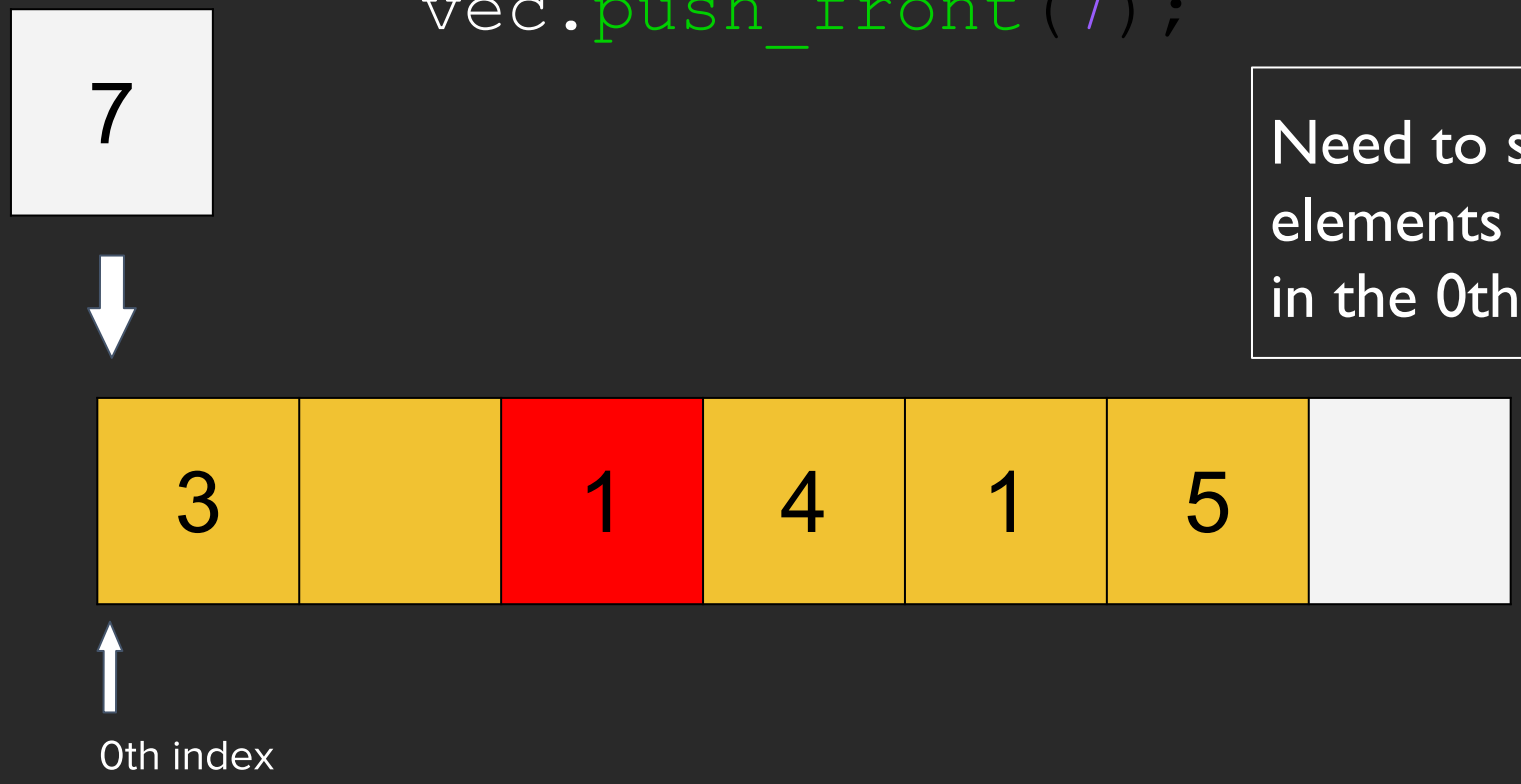


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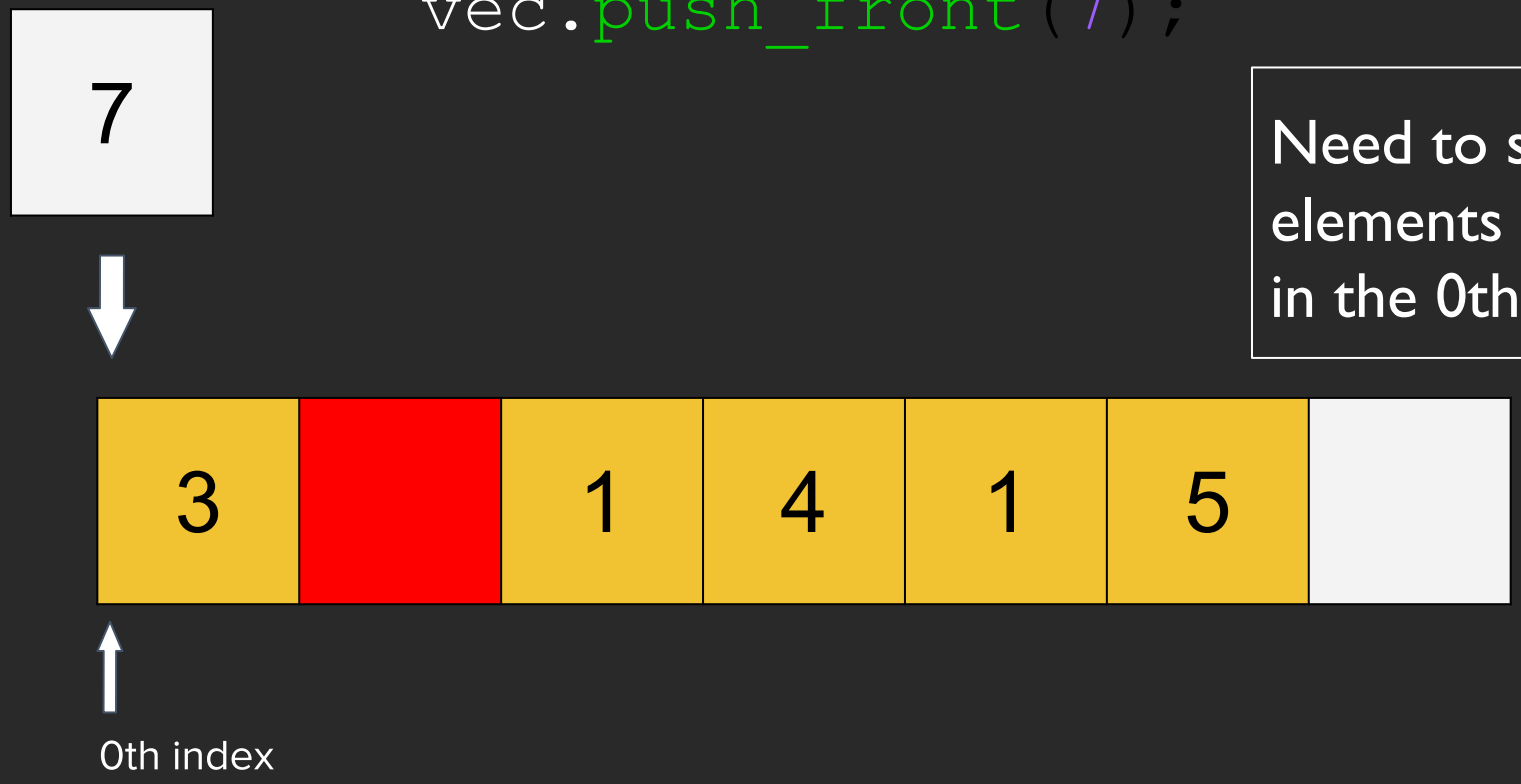


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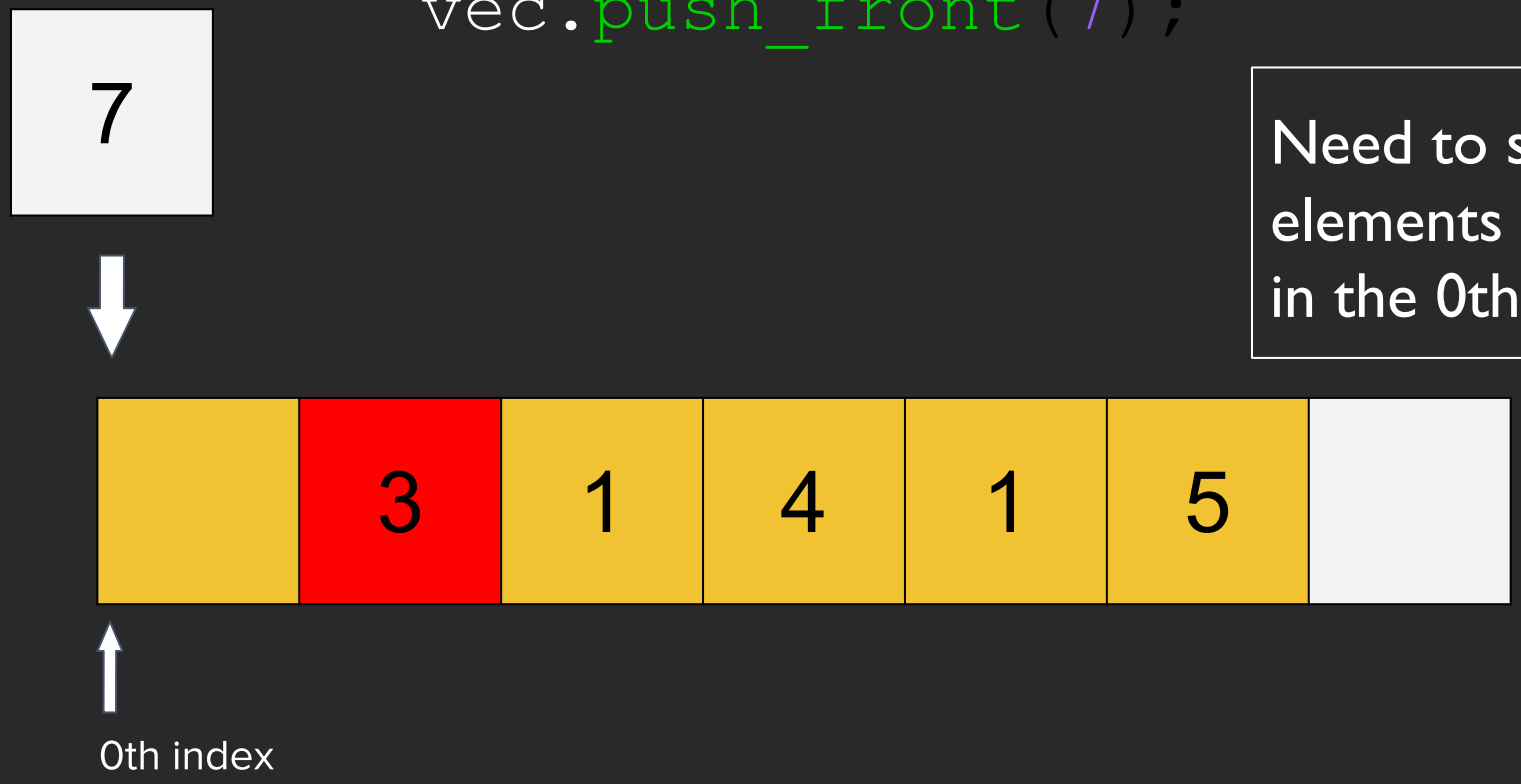


Need to shift these elements up to make space in the 0th position.

# What if we had a `push_front()`?

Suppose `push_front` existed and we used it.

Let's look at a small vector:

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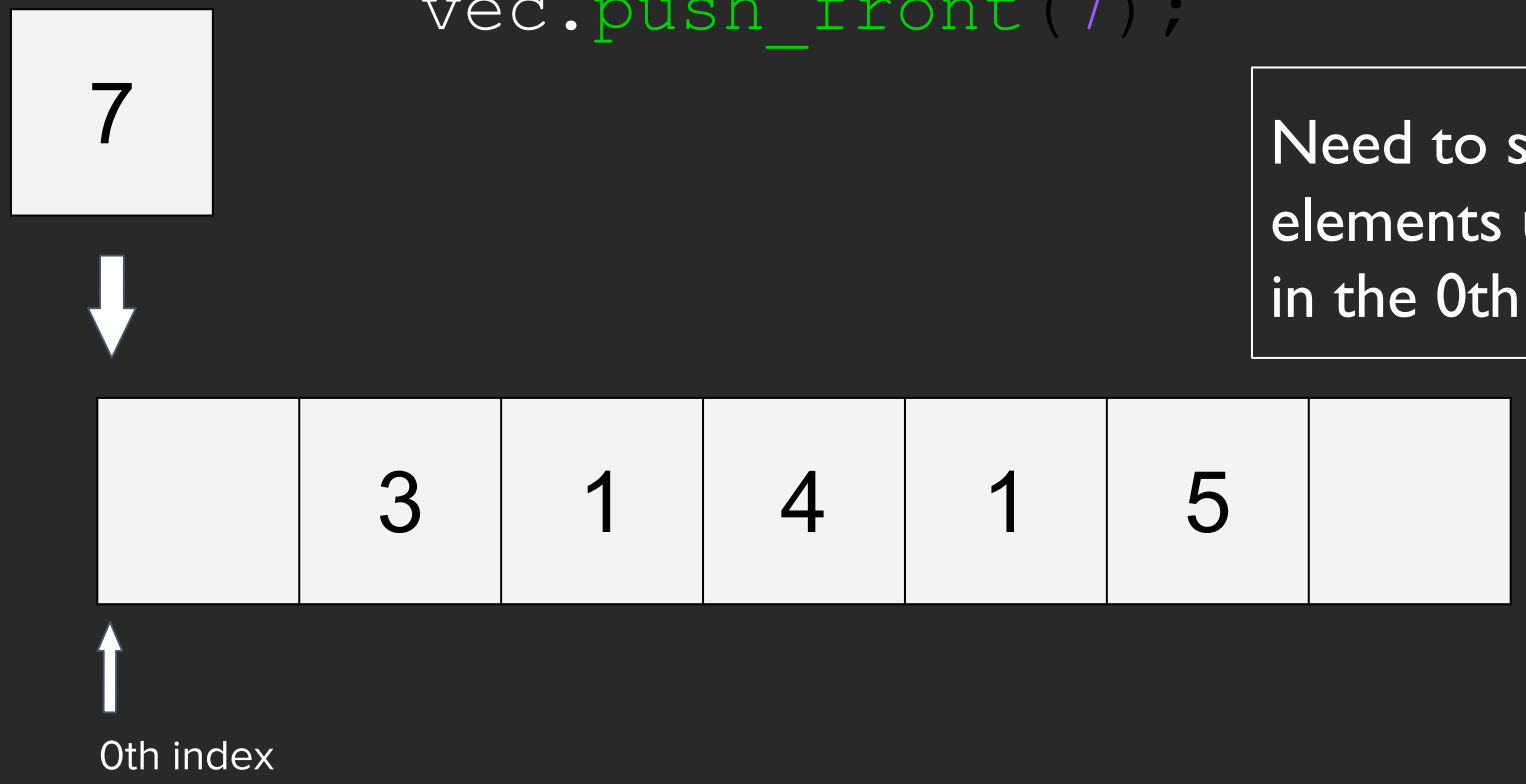


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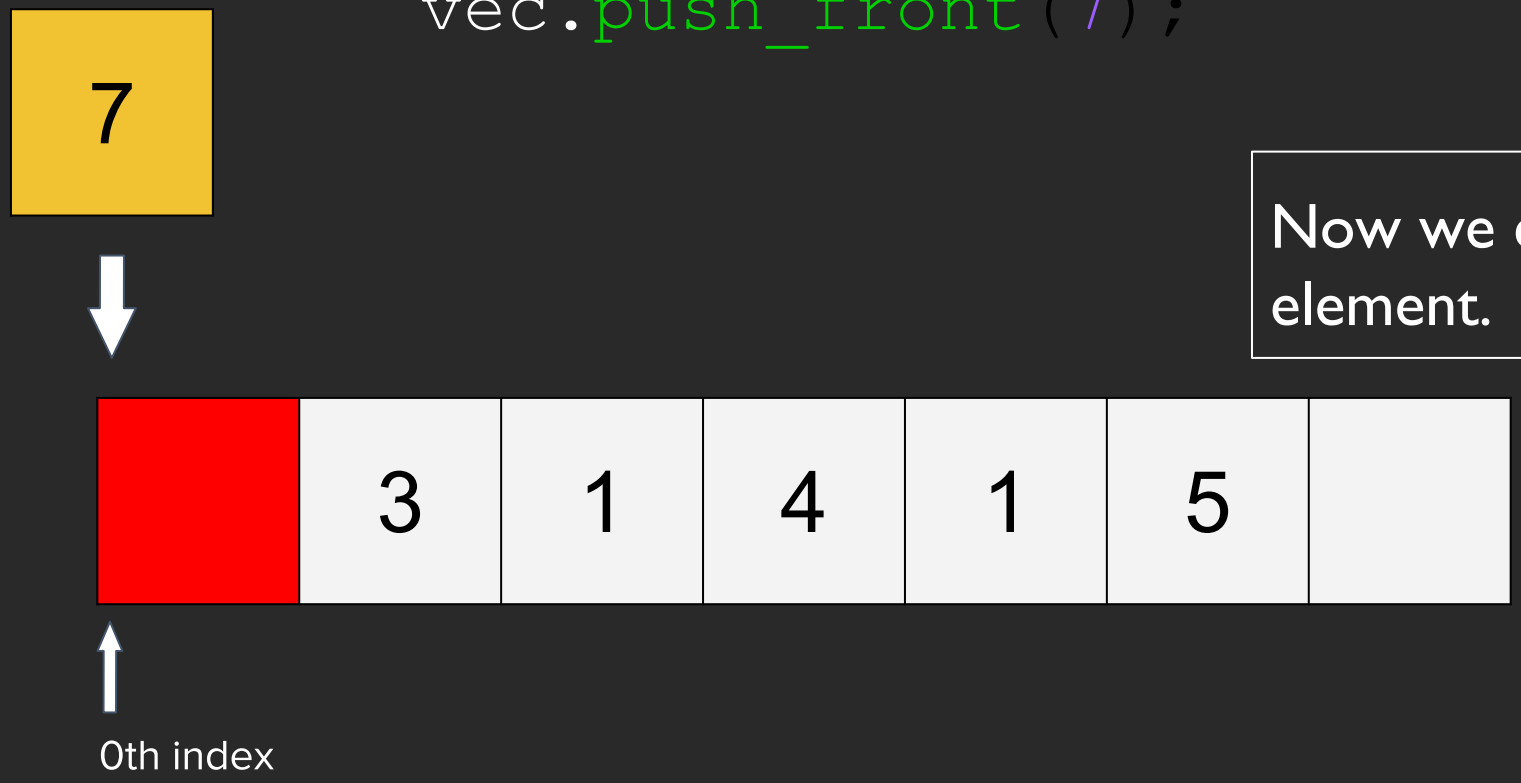


Now we can insert the new element.

# What if we had a `push_front()`?

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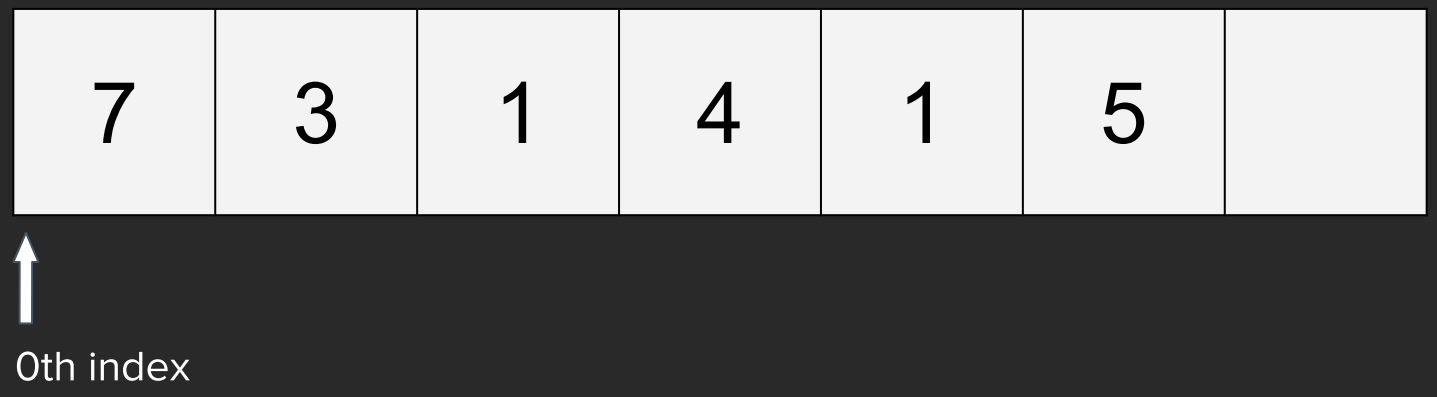


# What if we had a `push_front()`?


| 7 | 3 | 1 | 4 | 1 | 5 | |
|---|---|---|---|---|---|---|

0th index

# Conclusion: `push_front()` is slow!

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

- Fast
- Lightweight
- Intuitive

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

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

C++ has a solution!

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

# `std::deque<T>`

Pronounced “deck”.

Stands for a double ended queue.

Does everything a vector can do

AND

Unlike a vector, it is possible (and *fast*) to `push_front` and `pop_front`!

# Syntax of `std::deque<T>`

**/* Standard C++ Version */**

```
std::deque<int> d = { 1, 3, 7 };

d.push_back(271);
d.push_front(-1);

cout << d.front() << endl;
cout << d.back() << endl;

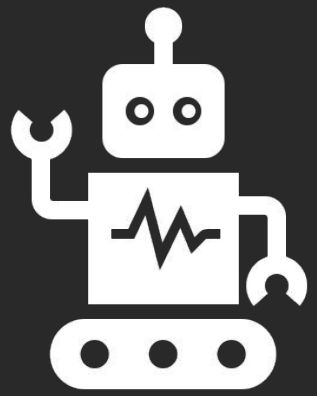
d.pop_back();
d.pop_front();
```

```
// d = {1, 3, 7}

// d = {1, 3, 7, 271}
// d = {-1, 1, 3, 7, 271}

// prints -1
// prints 271

// d = {-1, 1, 3, 7}
// d = {1, 3, 7}
```

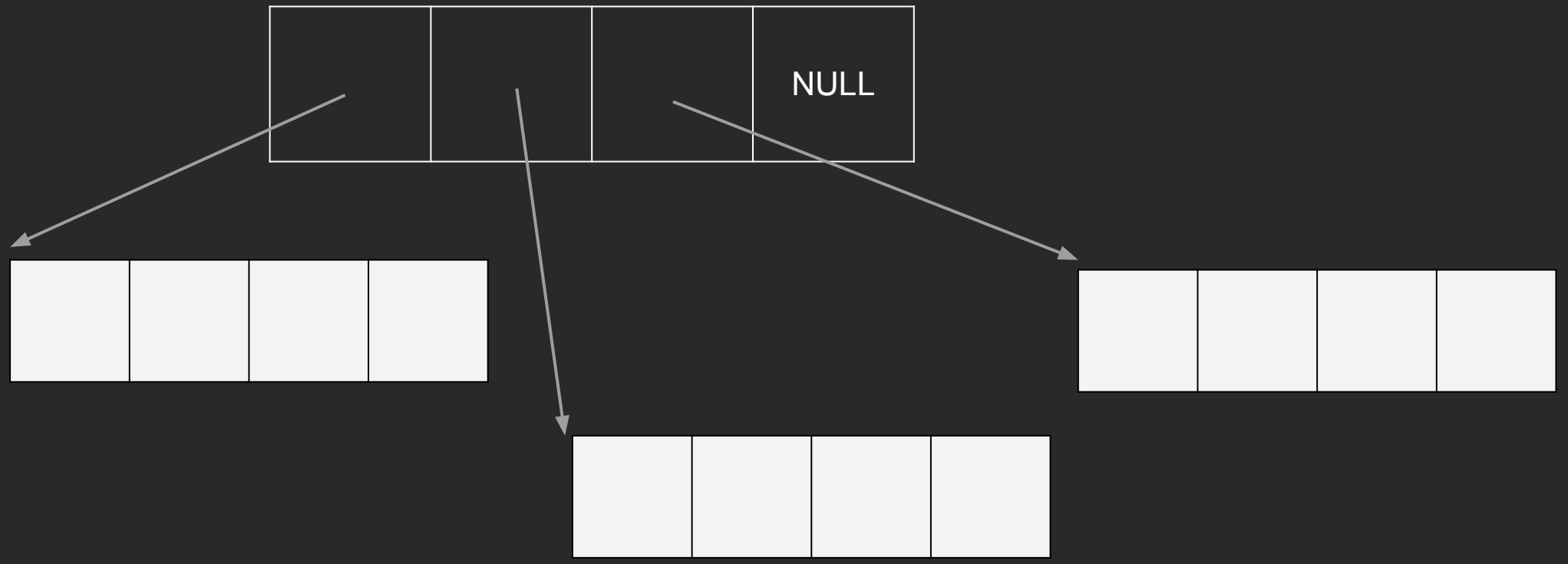


# Example

## Vector vs. Deque: `push_front`

# 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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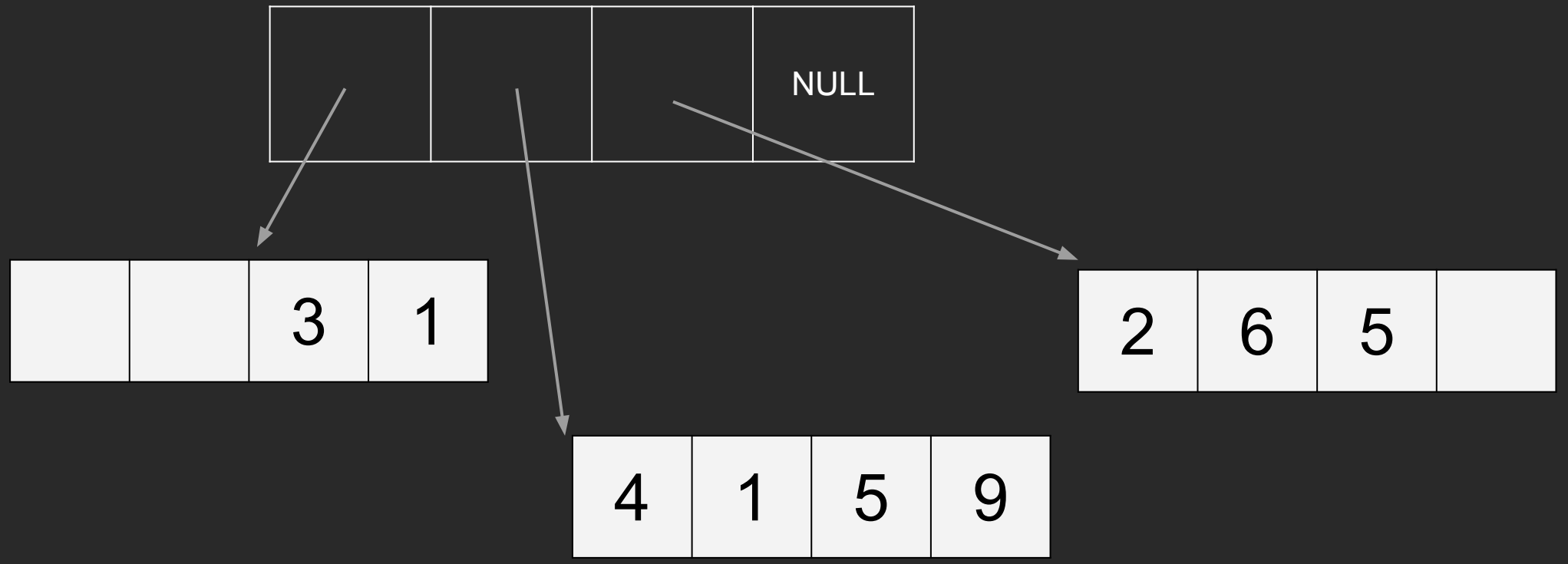

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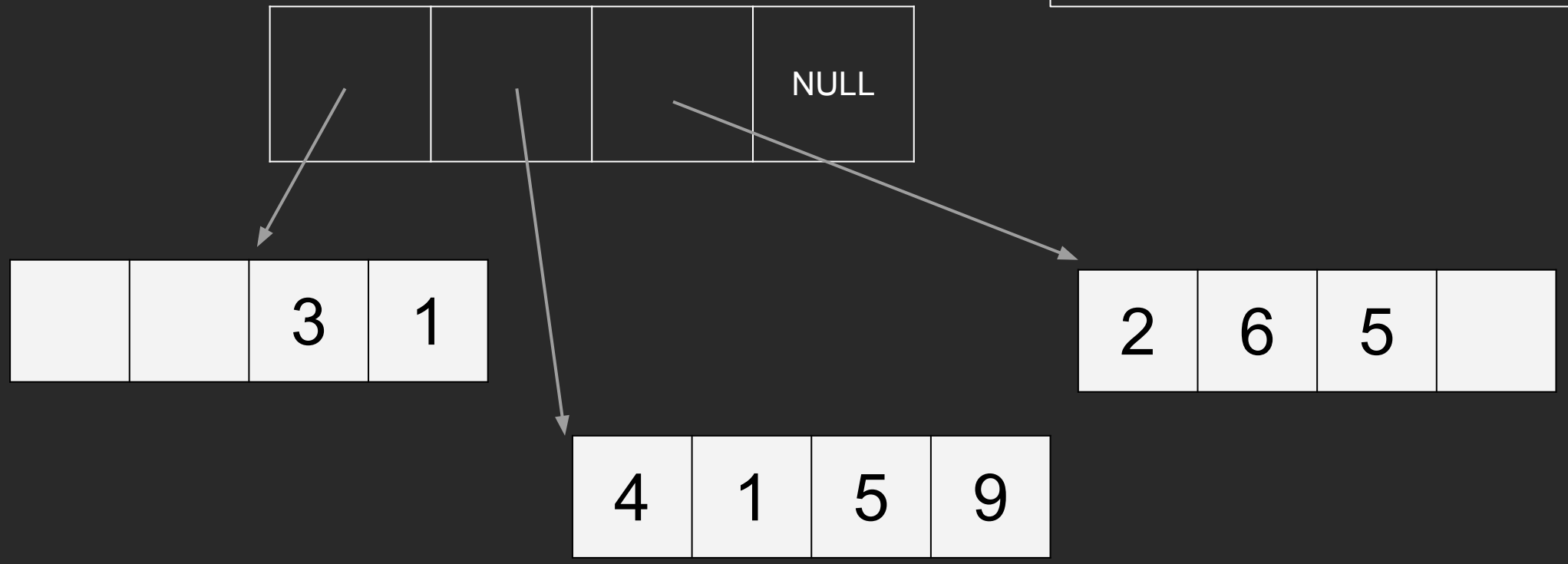

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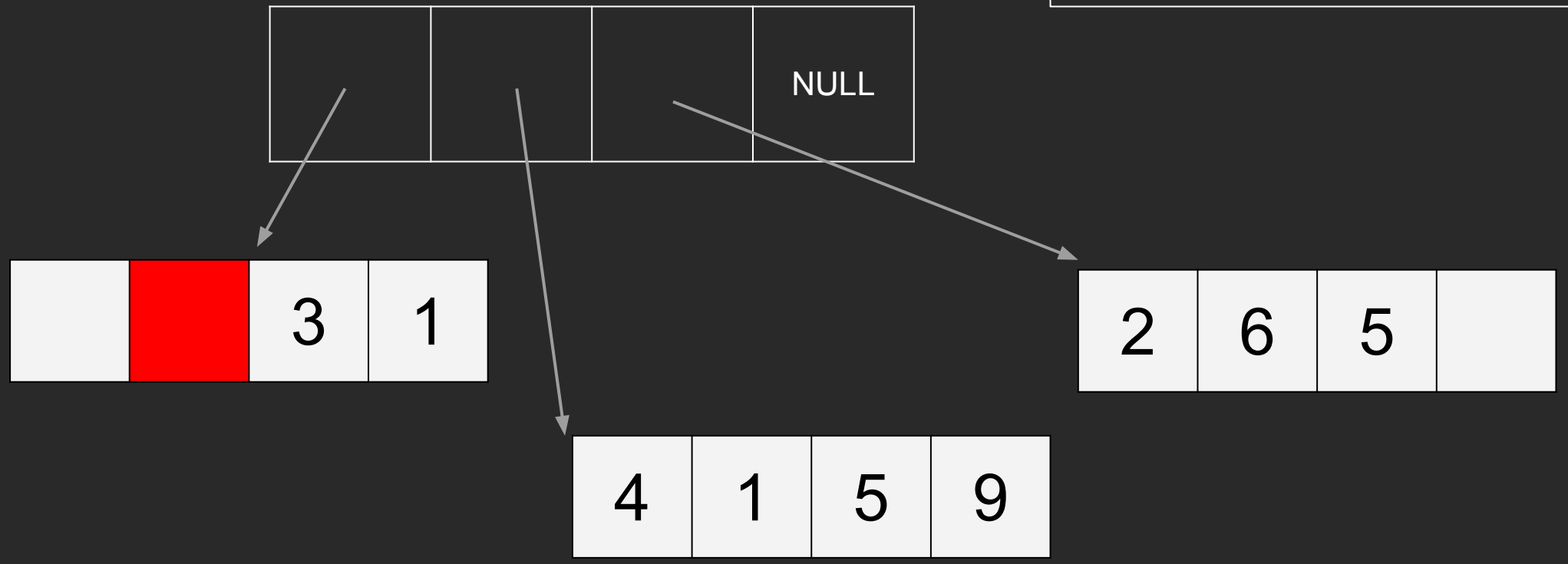

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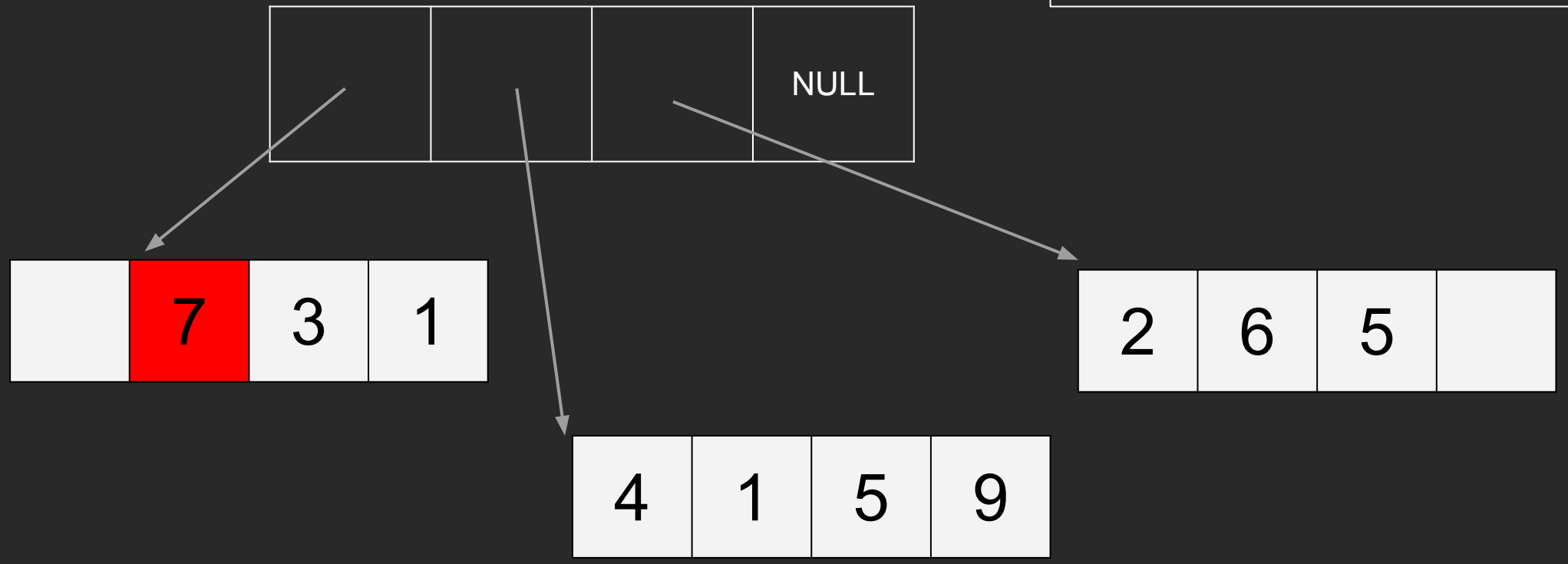

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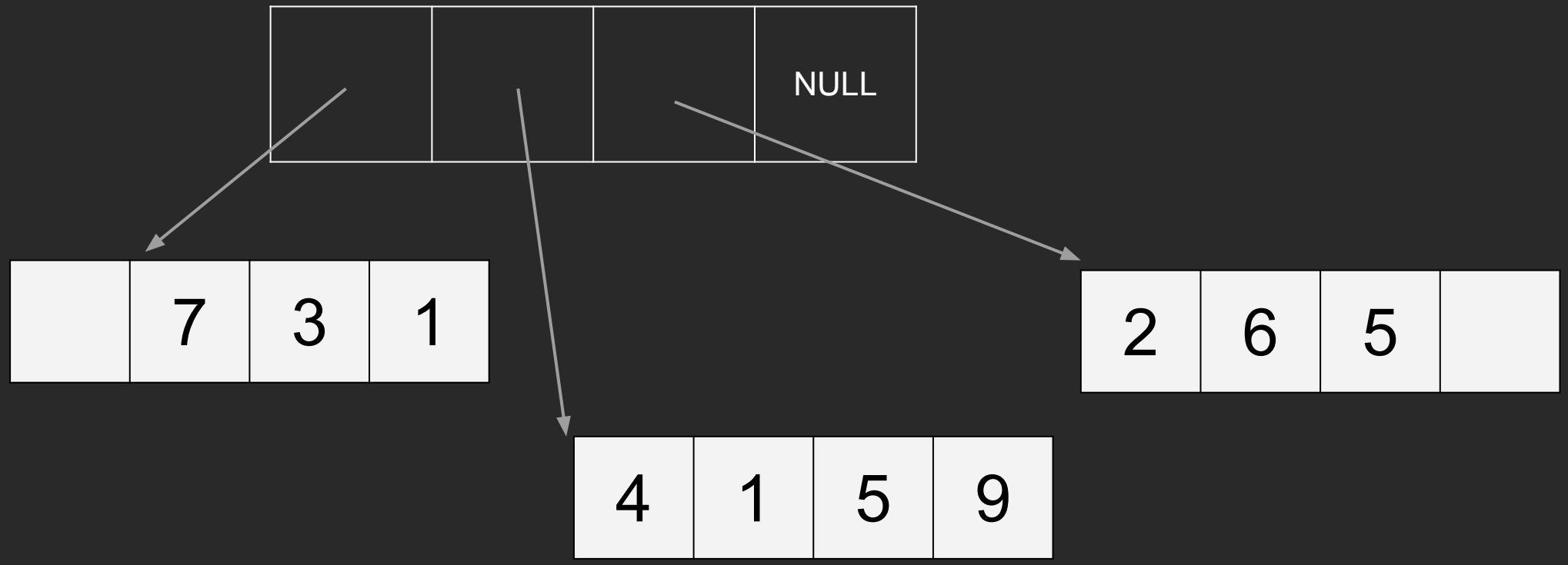

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There is no single specific implementation of a deque, but one common one might look like this:

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deq.push_back(3);
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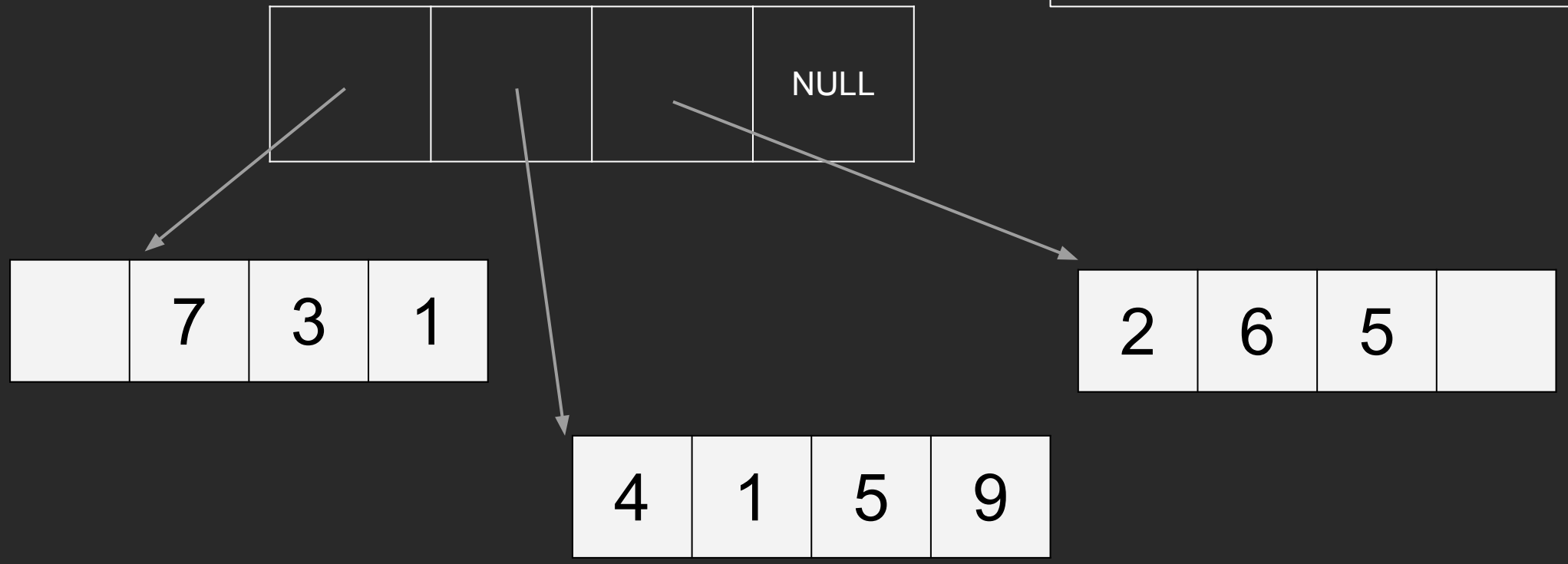

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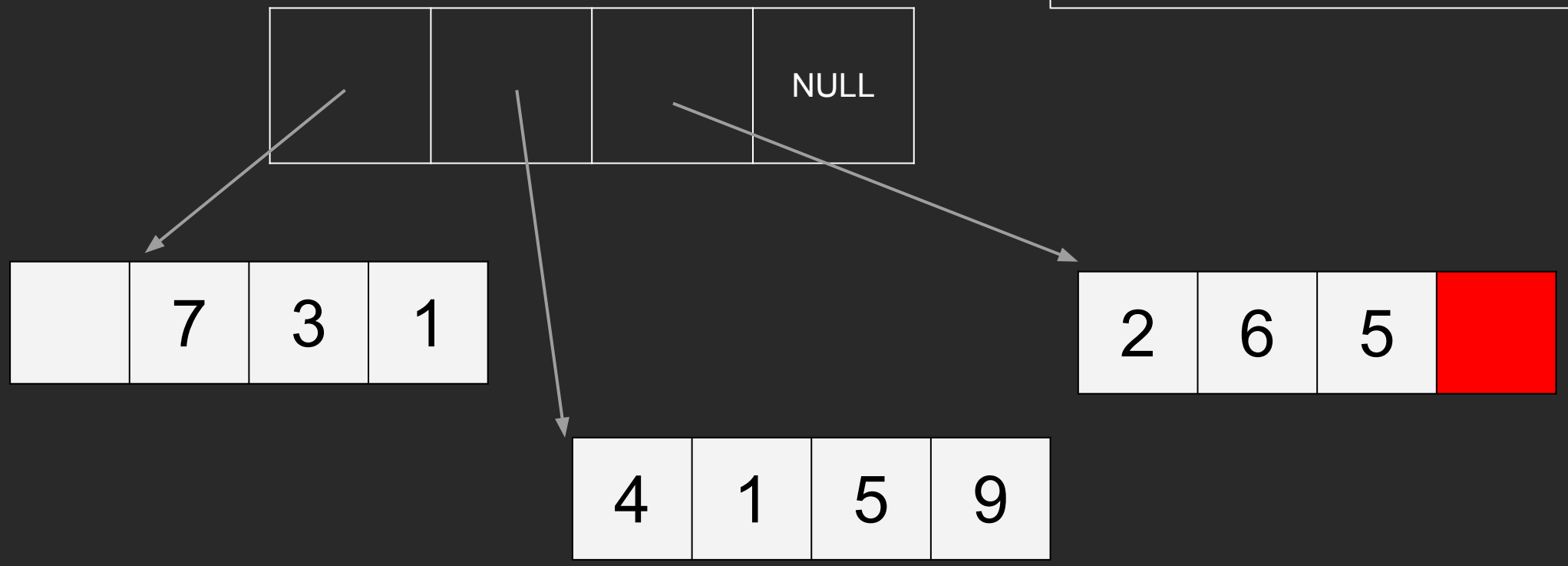

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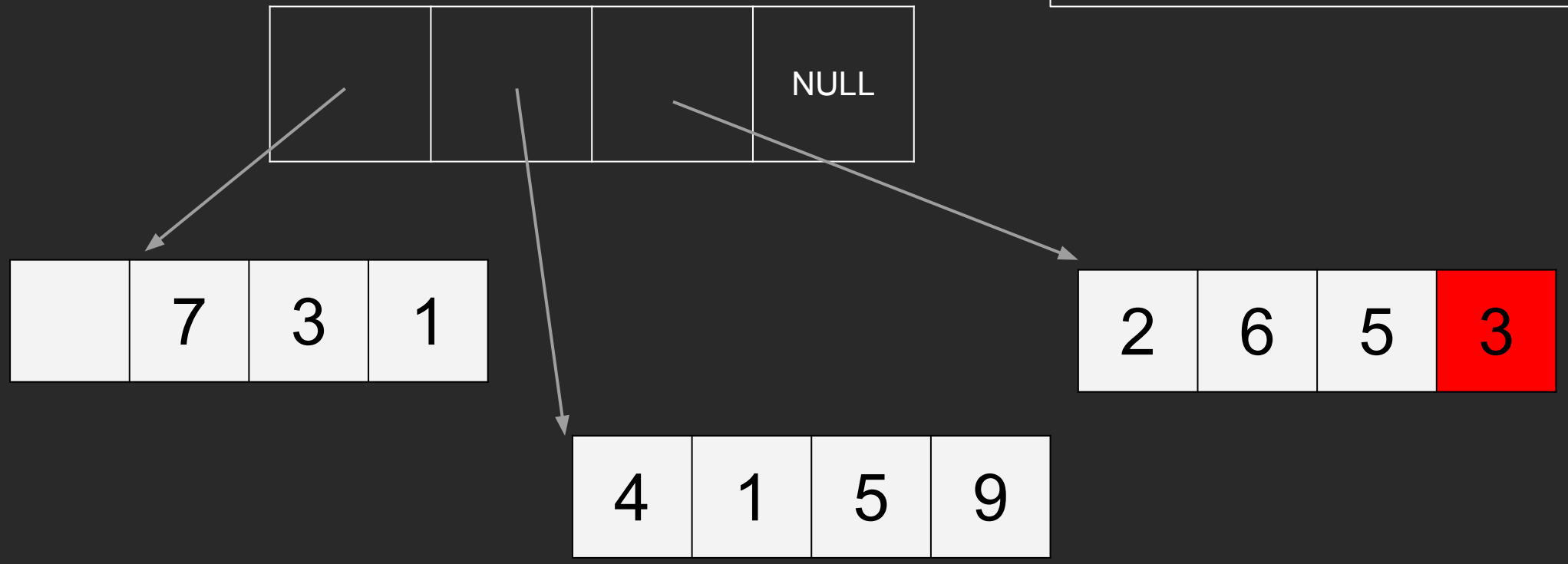

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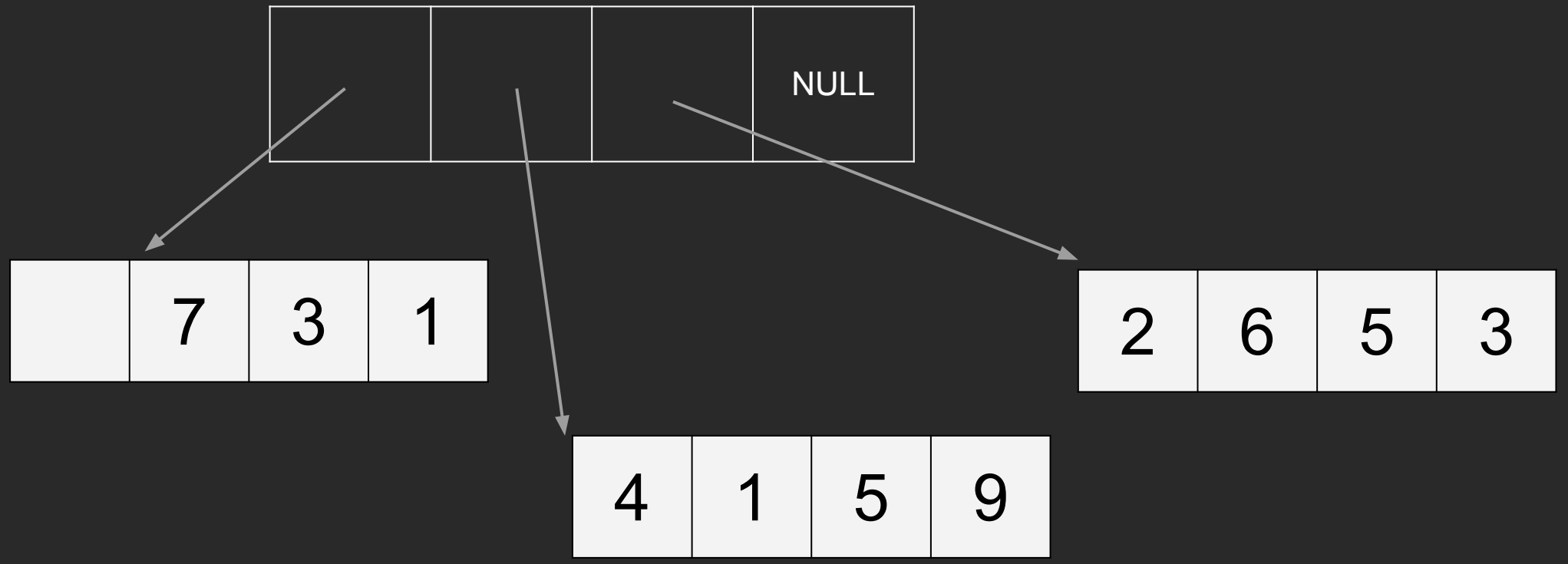

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deq.push_back(5);
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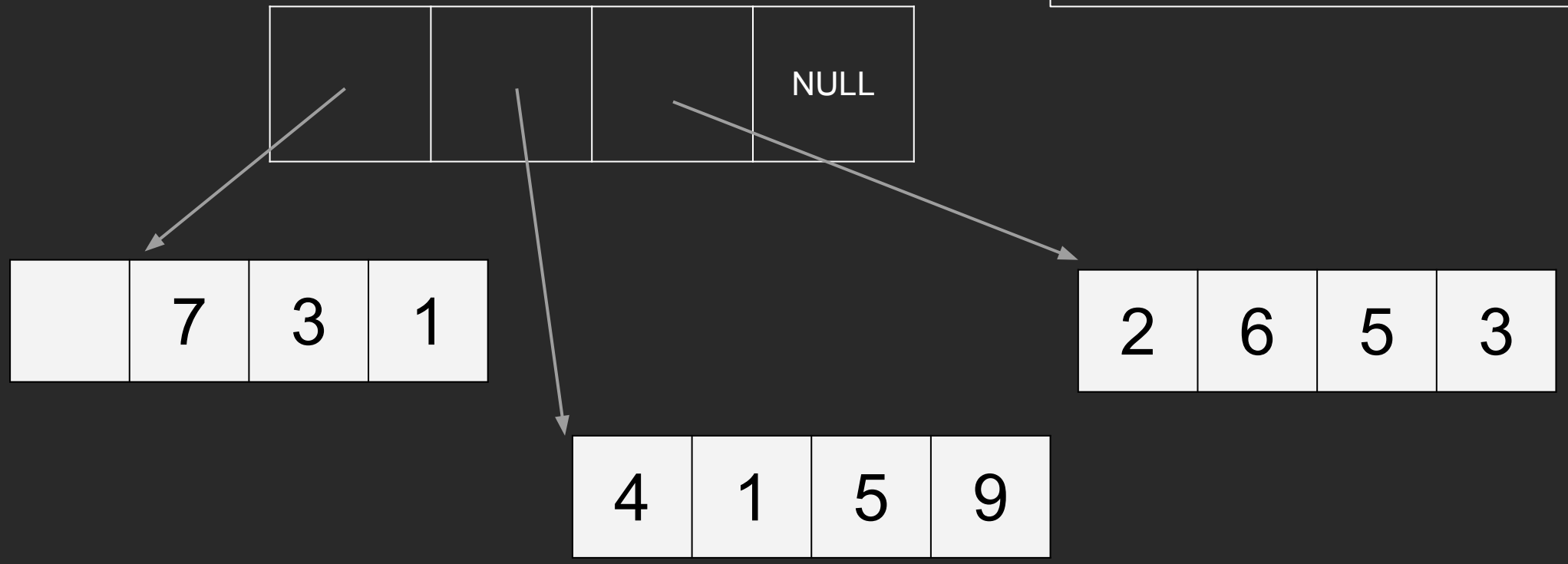

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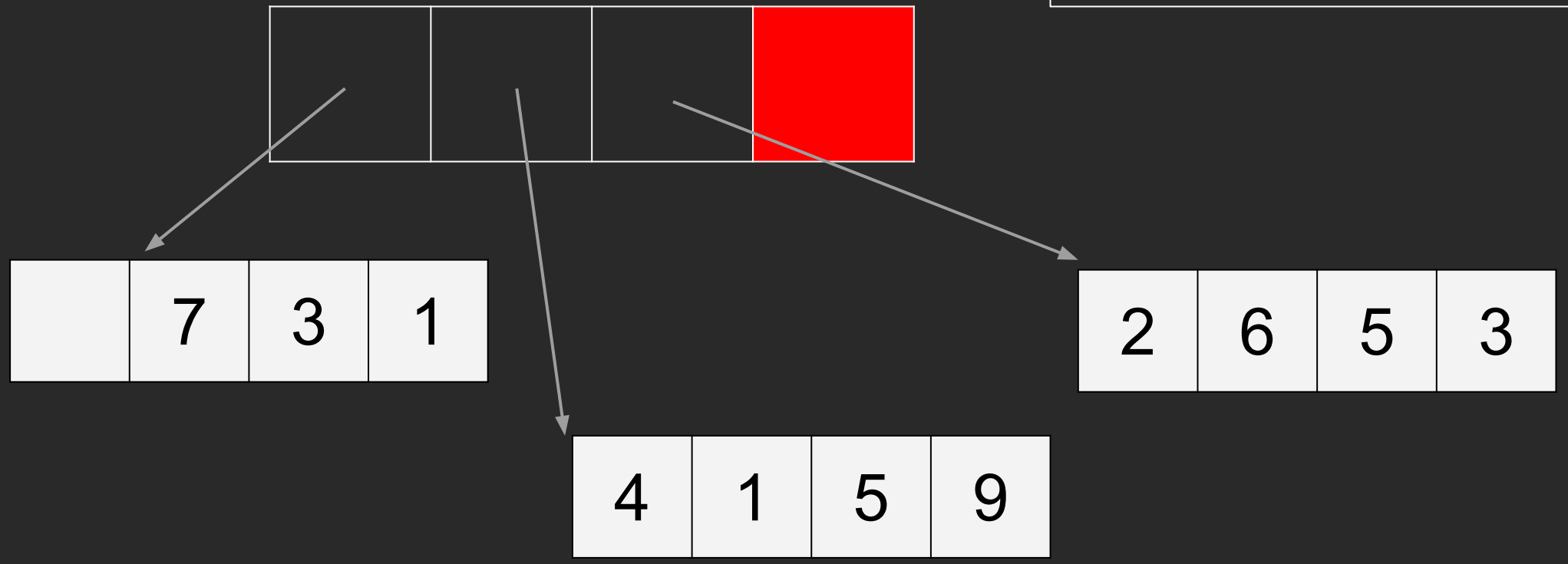

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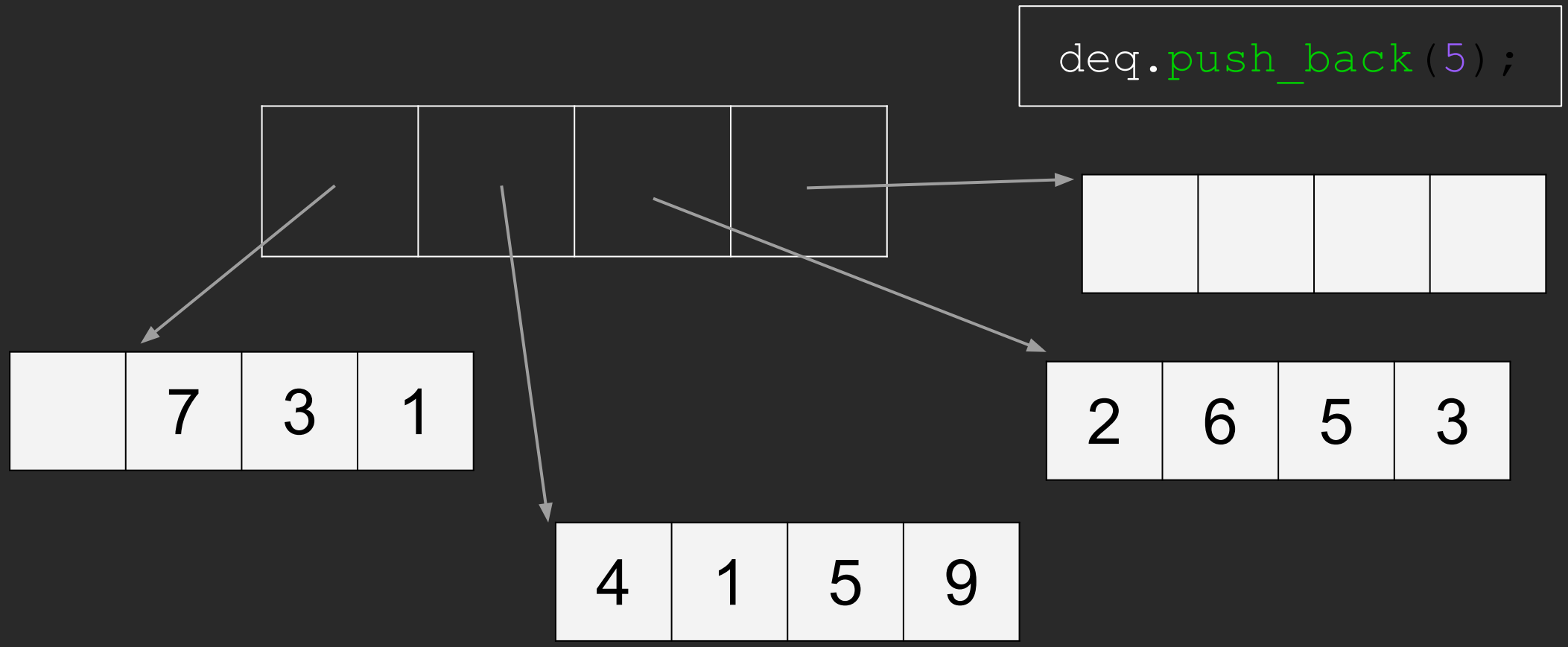

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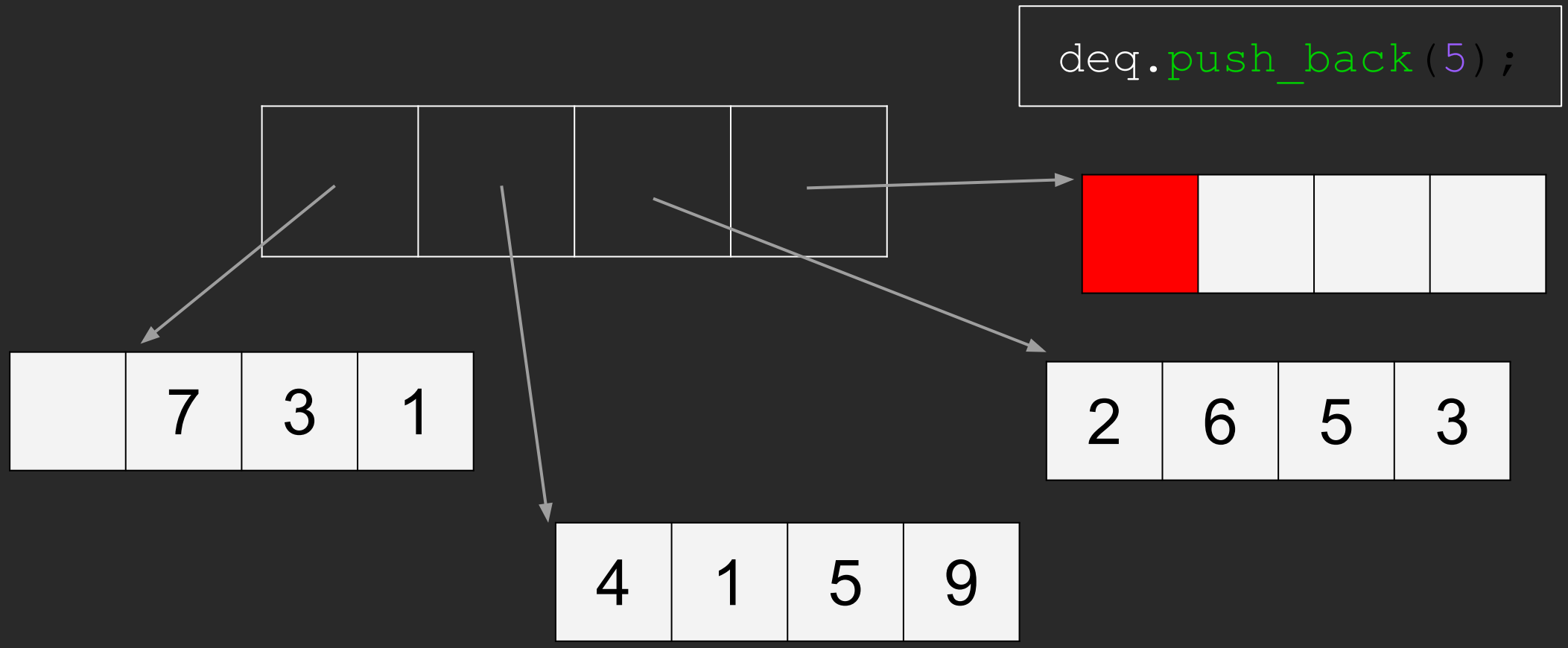

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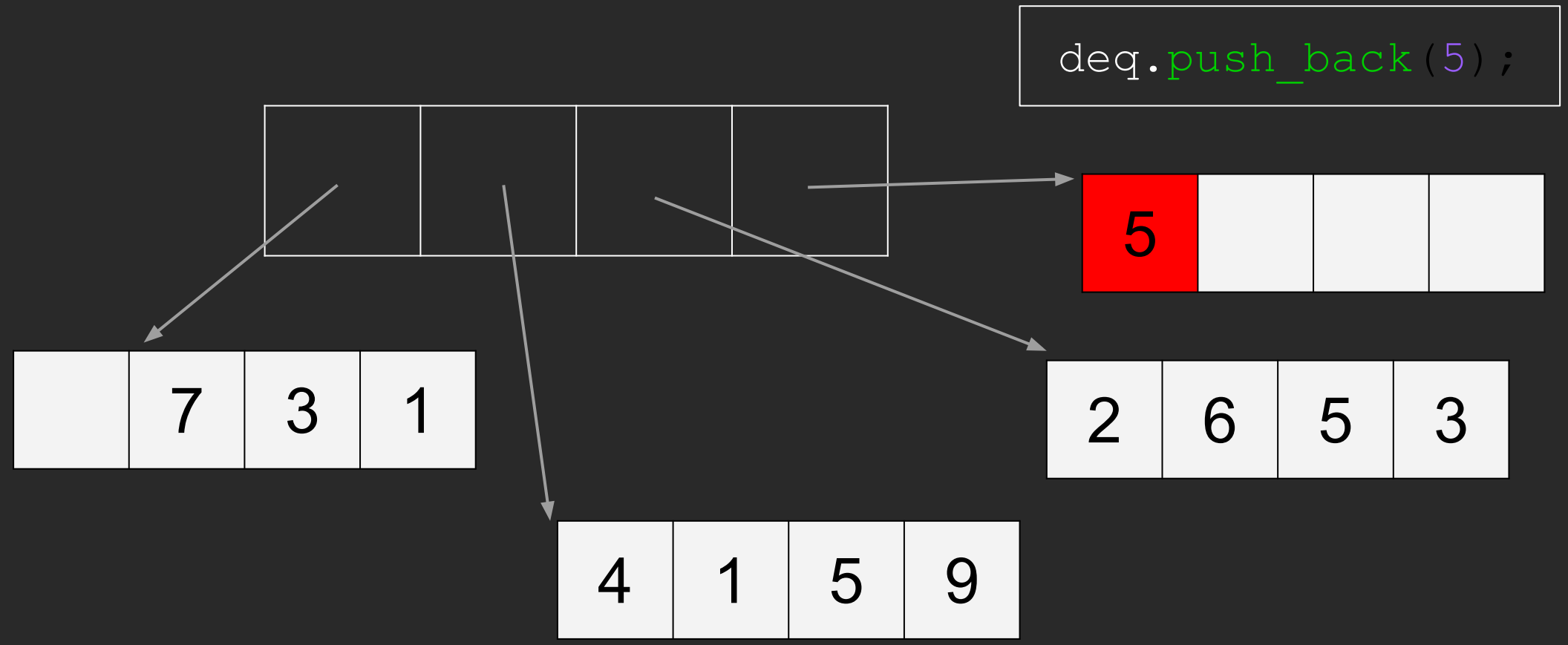

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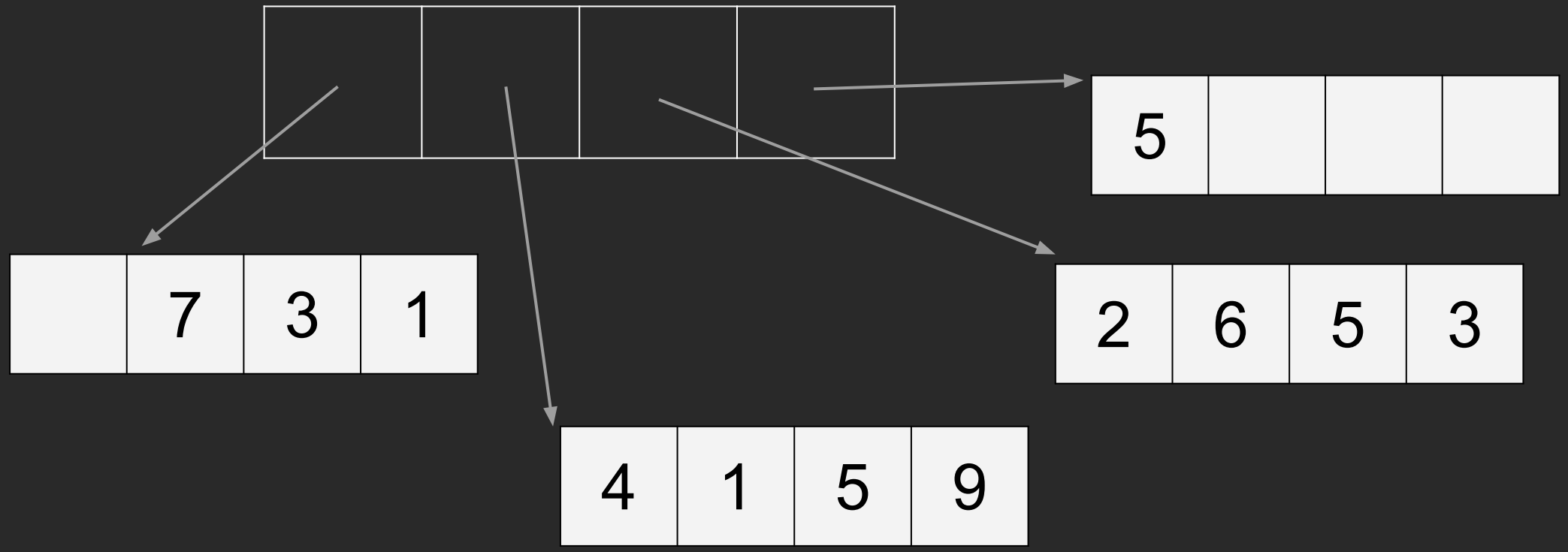


Wait a minute...

# Question

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

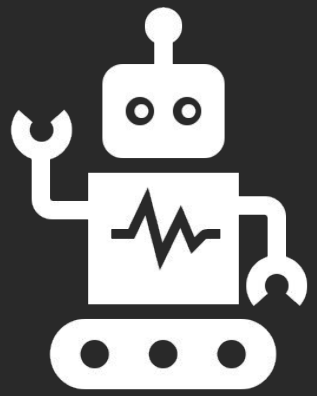
Why use a vector at all?

# Downsides of `std::deque<T>`

Deques support fast `push_front` operations.

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

Let’s see this in action!



# Example

## Vector vs. Deque: Element Access

# Which to Use?

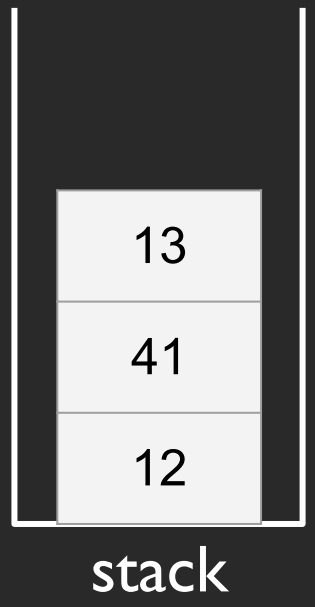
*“vector is the type of sequence that should be used by default... deque is the data structure of choice when most insertions and deletions take place at the beginning or at the end of the sequence.”*

— C++ ISO Standard (section 23.1.1.2):

# Container Adaptors

# Container Adaptors

Recall stacks and queues:



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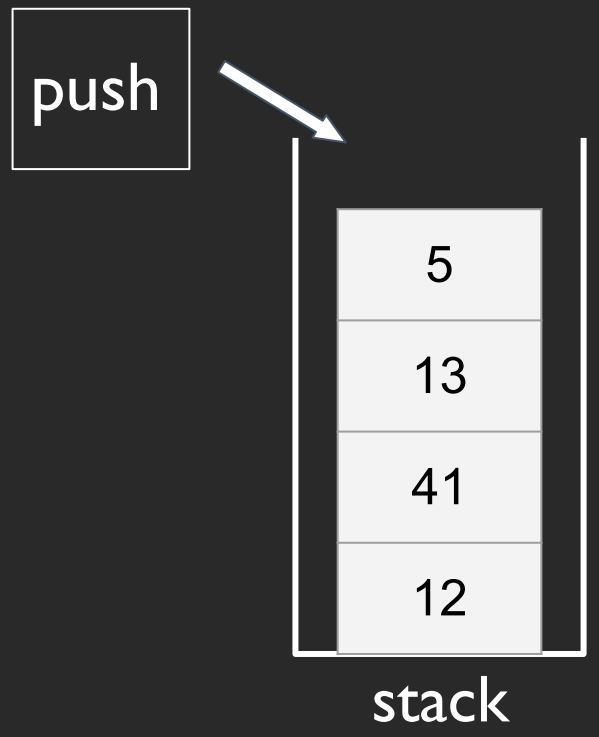

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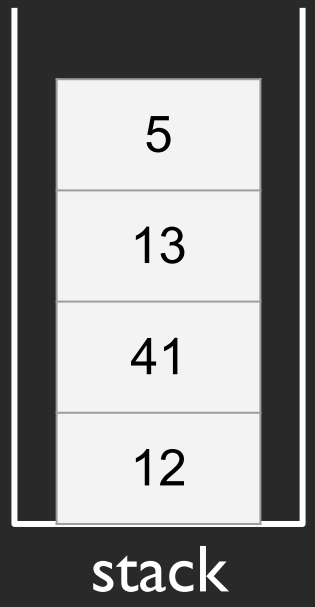

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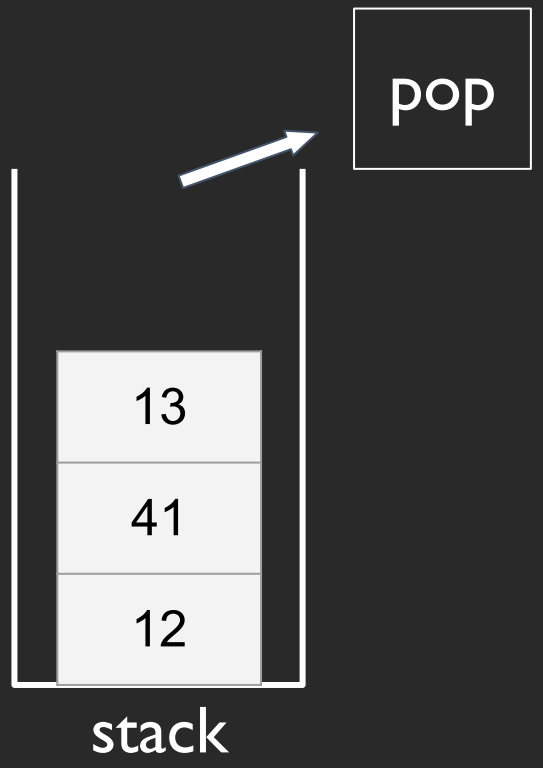

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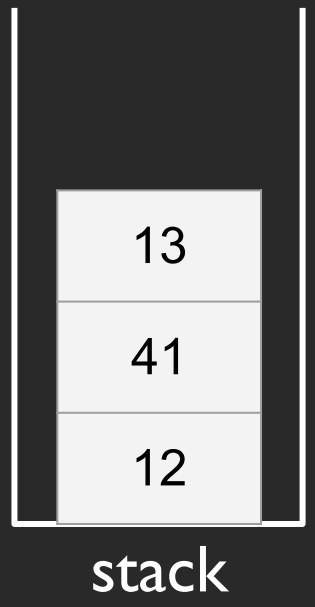

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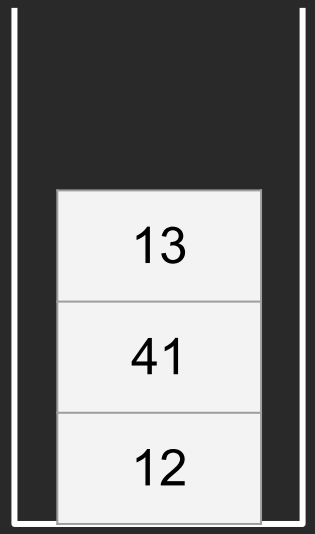
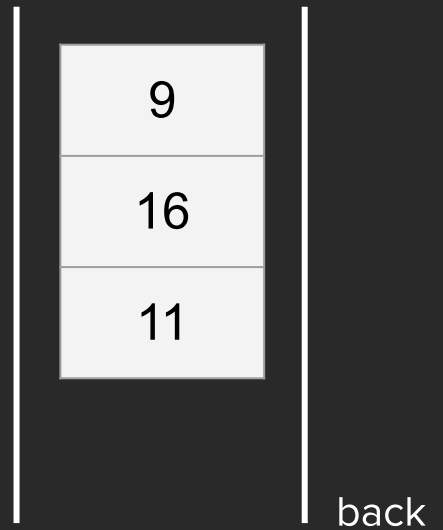



stack




queue

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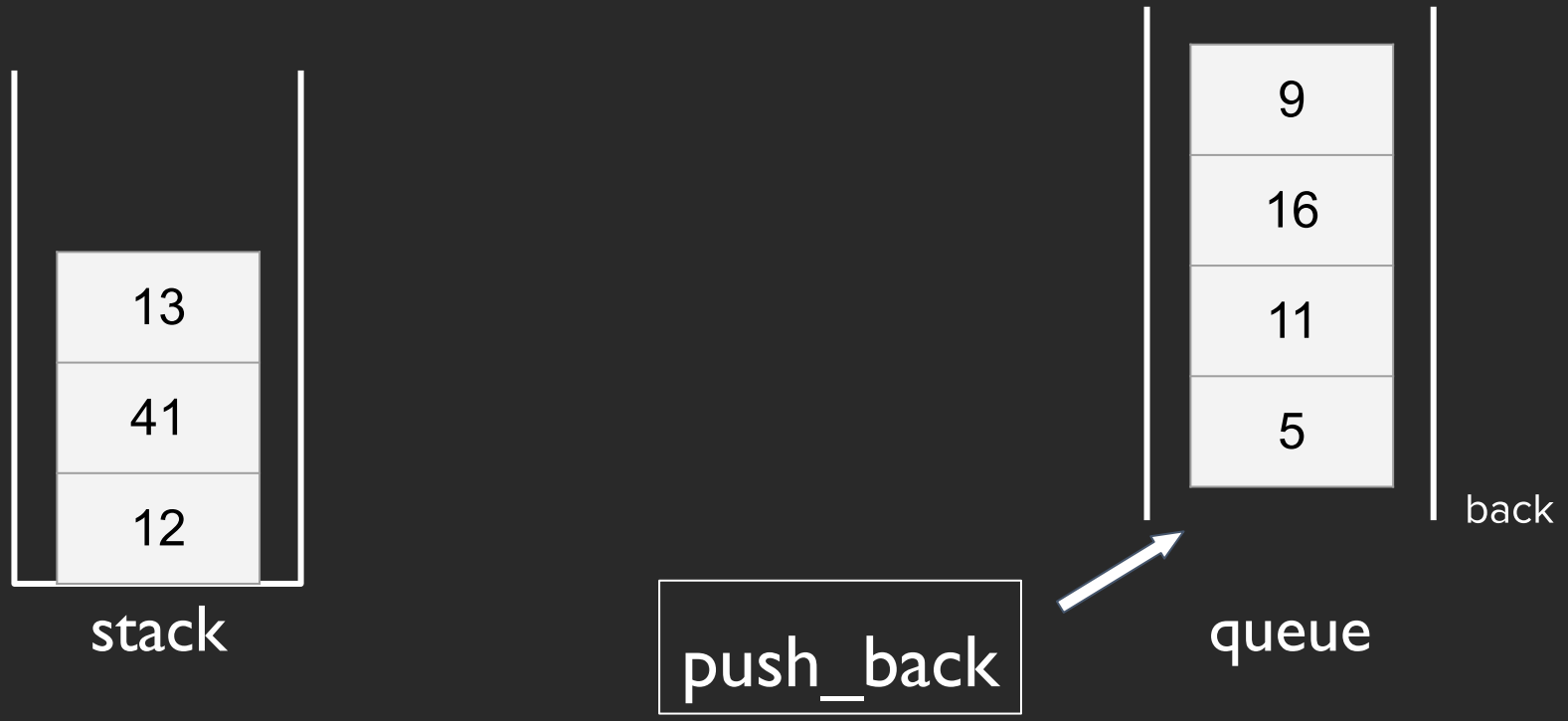

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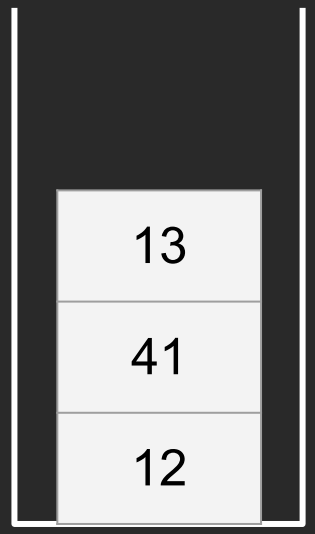


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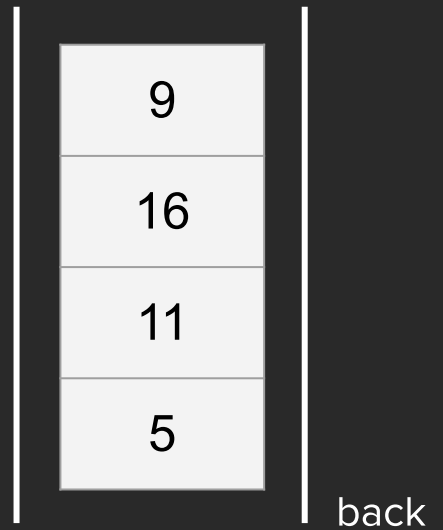


queue

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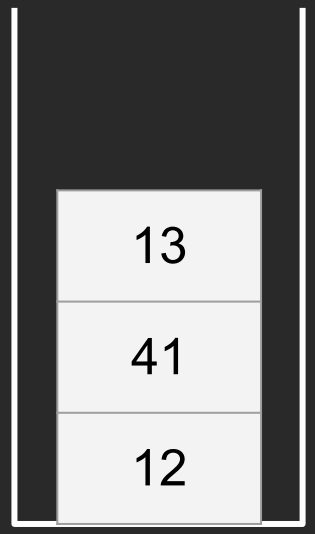


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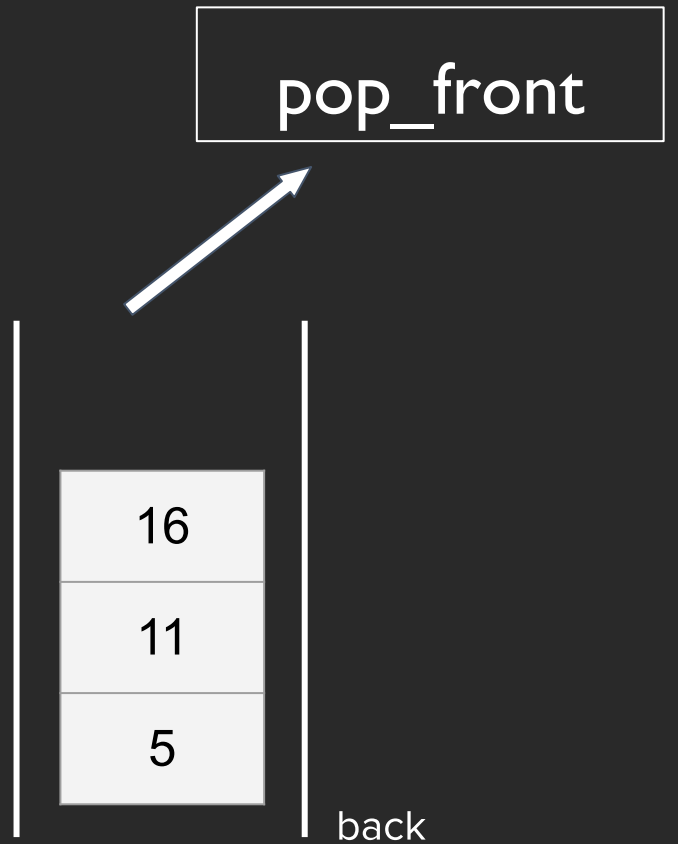


queue

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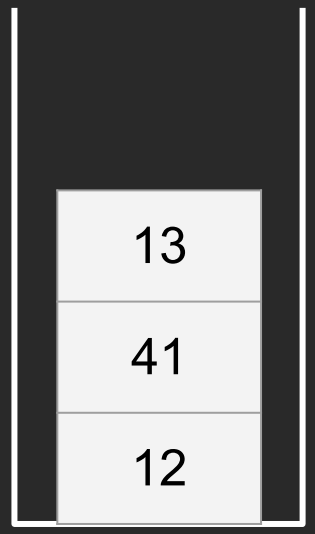


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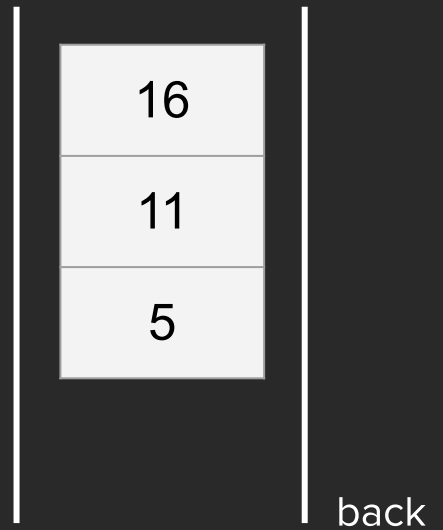


queue

# Container Adaptors

How can we implement stack and queue using the containers we have?

# Container Adaptors

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 Adaptors

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

## std::stack

Defined in header <stack>

```
template<
    class T,
    class Container = std::deque<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++17)

**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>

```
template<
    class T,
    class Container = std::deque<T>
> class queue;
```

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.

The class template acts as a wrapper to the underlying container - only a specific set of functions is provided. The queue pushes the elements on the back of the underlying container and pops them from the front.

### 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++17)

**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()`
- `front()`
- `push_back()`
- `pop_front()`

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

# Container Adaptors

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

## std::stack

Defined in header <stack>

```
template<
    class T,
    class Container = std::deque<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++17)

**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>

```
template<
    class T,
    class Container = std::deque<T>
> class queue;
```

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.

The class template acts as a wrapper to the underlying container - only a specific set of functions is provided. The queue pushes the elements on the back of the underlying container and pops them from the front.

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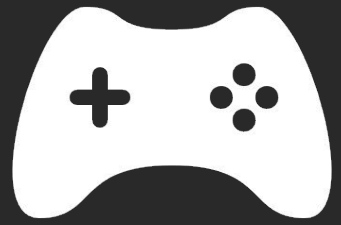
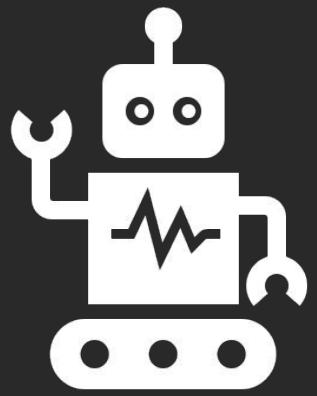


# Next time

Iterators and Associative Containers

# Bonus Content...



# Example

## The Power of the C++ STL

# Where we are going...

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

```
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"));
```

stream iterator