CS 261: Data Structures

Dynamic Array Queue

Dynamic Array -- Review

- Positives:
  - Each element easily accessed
  - Grows as needed
  - The user unaware of memory management

Stack as Dynamic Array -- Review

- Remove and add elements from/to top
- Occasional capacity increase
- Remove operation has complexity O(1)
- Add operation has complexity O(1)

Bag as Dynamic Array -- Review

- Order is not important, so adding to the end
- Add is O(1), with occasional capacity increase
- Remove is O(n)

Dynamic Array -- Problems

- Data kept in a single large block of memory
- Often more memory used than necessary
  - especially when more frequently removing elements than adding elements
- Inefficient for implementation of other ADT

Queue

Queue

- Elements are inserted at one end, and removed from another
- E.g. line of people
- First in, first out (FIFO)

Interface View of Queue

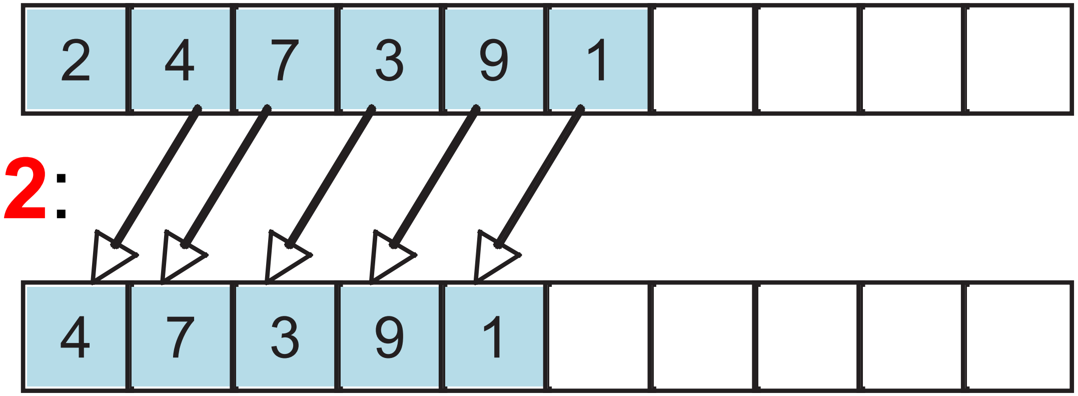
- addBack(newElement) -- inserts an element
- front() -- returns the first element
- removeFront() -- removes the first element
- isEmpty() -- checks if the queue is empty

Queue as Dynamic Array

- Which end is better for insertion?
- Which end is better for removal?
- What would be O(?) ?

Removing from Front, Adding to Back using Dynamic Arrays

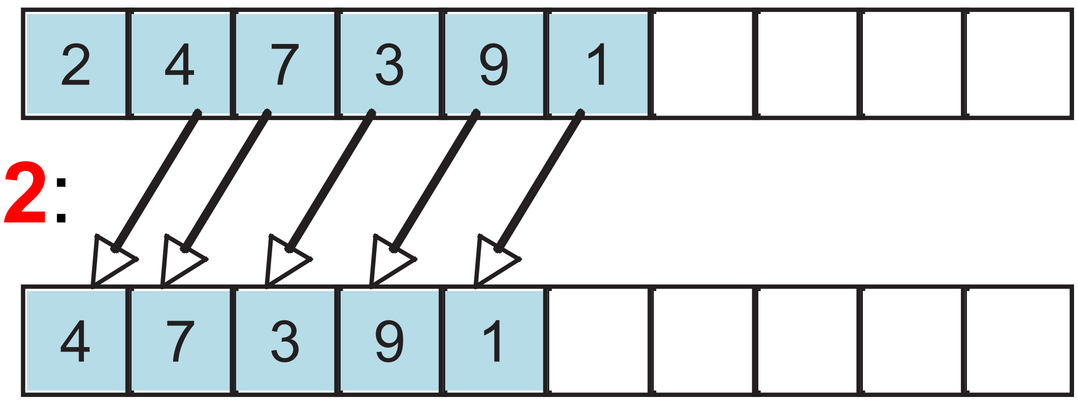
Remove **2**:



Remove requires moving elements => **O(n)**

Removing from Front, Adding to Back using Dynamic Arrays

Remove **2**:



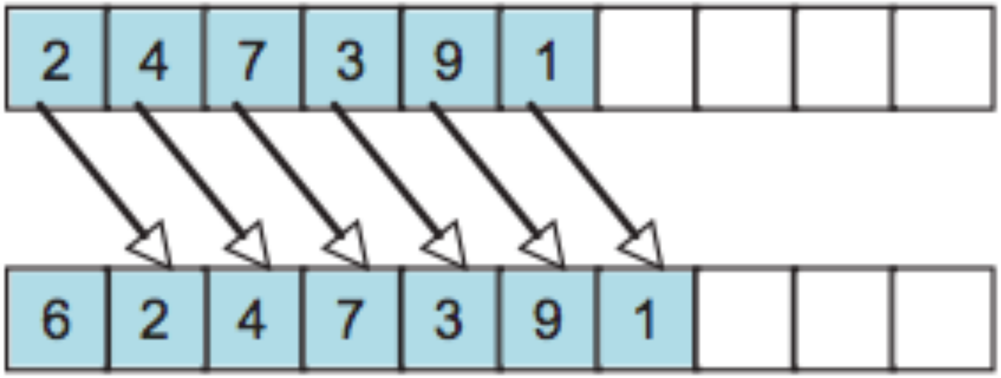
Remove requires moving elements => **O(n)**

Inefficient

Insertion to the end is O(1)

Removing from Back, Adding to Front using Dynamic Arrays

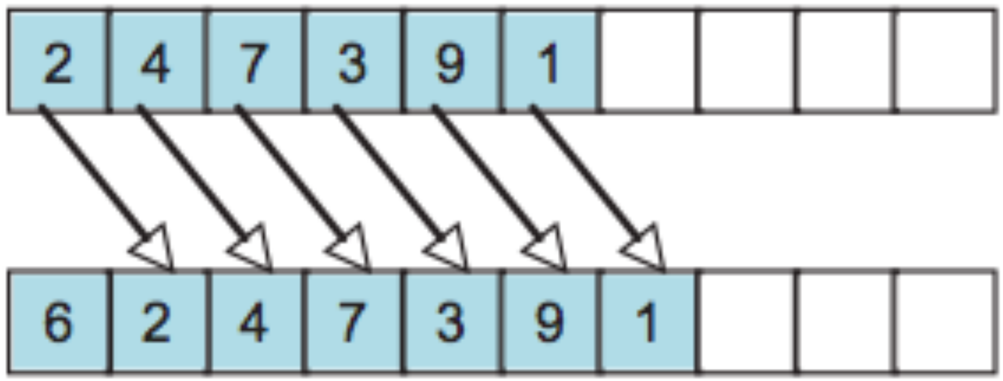
Add **6**:



Add requires moving elements => **O(n)**

Removing from Back, Adding to Front using Dynamic Arrays

Add **6**:

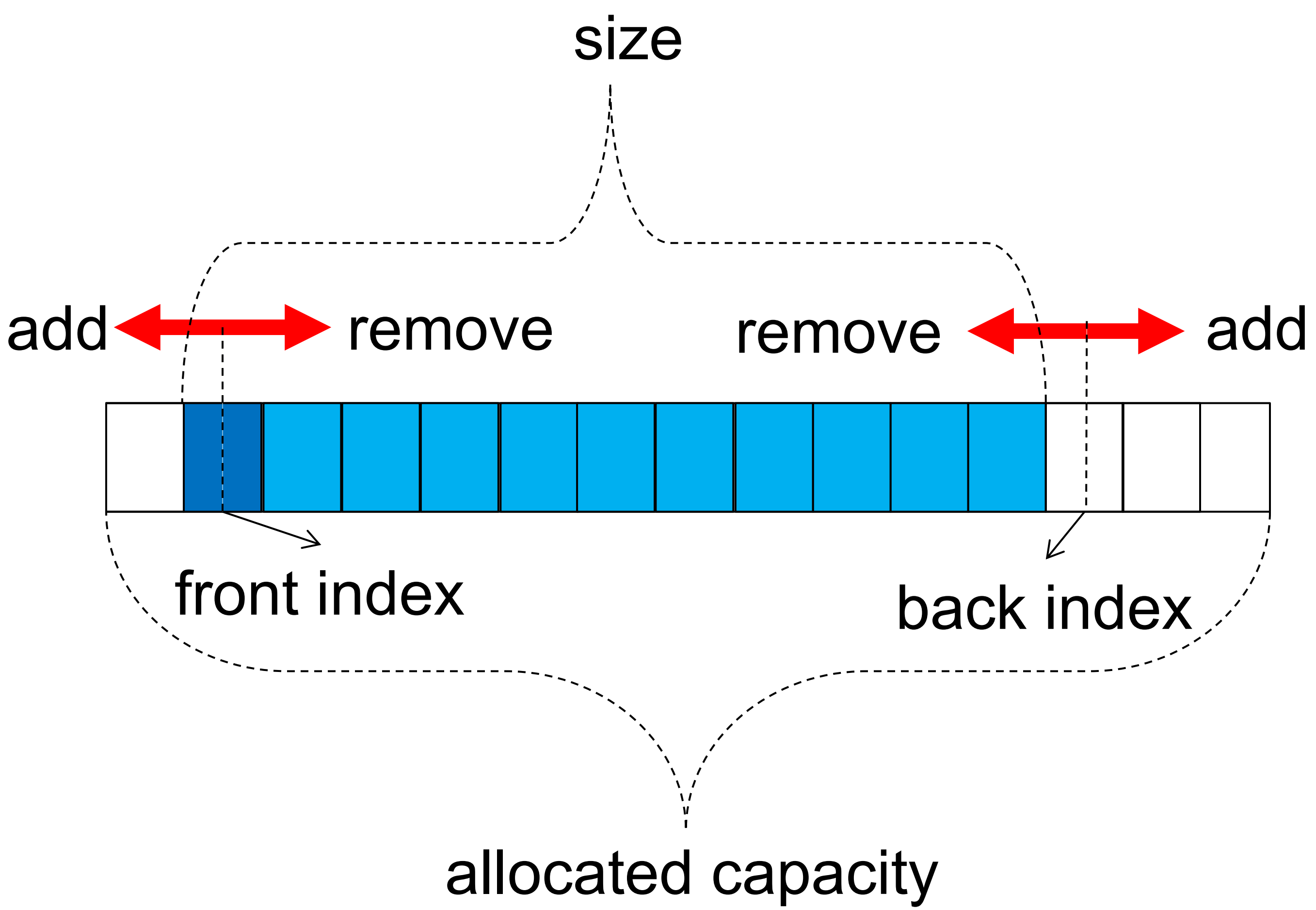


Add requires moving elements => **O(n)**

Inefficient

Removal from the end is O(1)

Deque


size
add
remove
remove
add
front index
back index
allocated capacity

Deque

- Allows:
  - Insertions at both front and back
  - Removals at both front and back
- Stack, Queue → Special case of Deque
- Deque → Two end-to-end stacks

Interface View of Deque

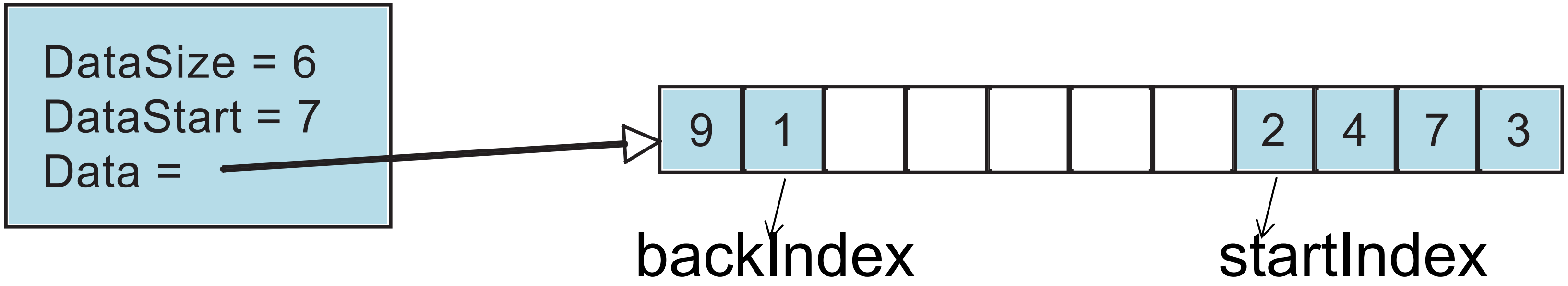
- addFront(newElem) -- inserts to the front
- addBack(newElem) -- inserts to the back
- front() -- returns the first front element
- back() -- returns the first back element
- removeFront() -- removes from the front
- removeBack() -- removes from the back
- isEmpty() -- checks if the queue is empty

Deque as Dynamic Array

- **Key idea**:
  - Do not tie "front" to index zero
- Instead,
  - allow both "front" and "back" to float around the array

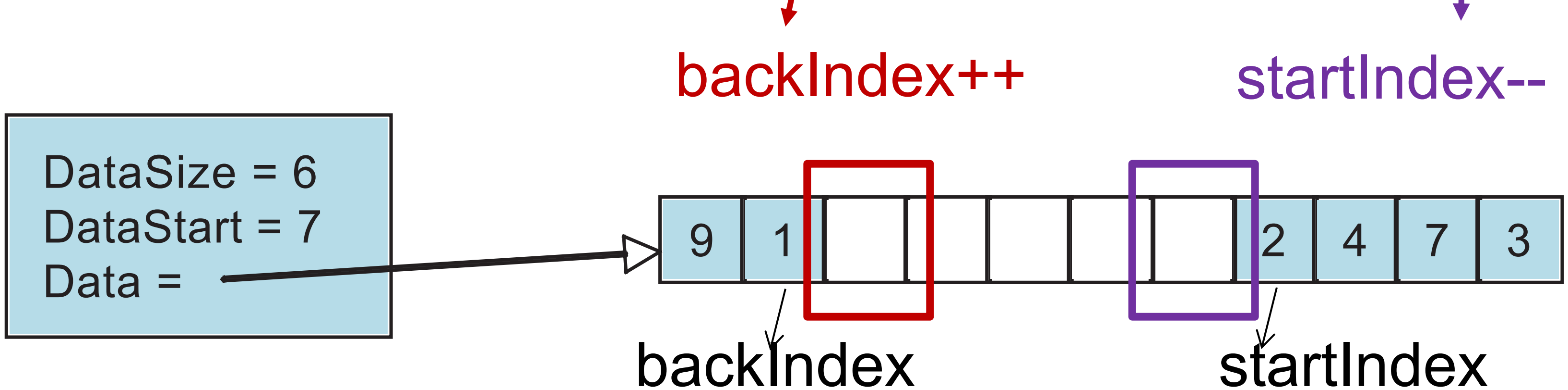
Example Deque

In this example, start index is **larger** than back index



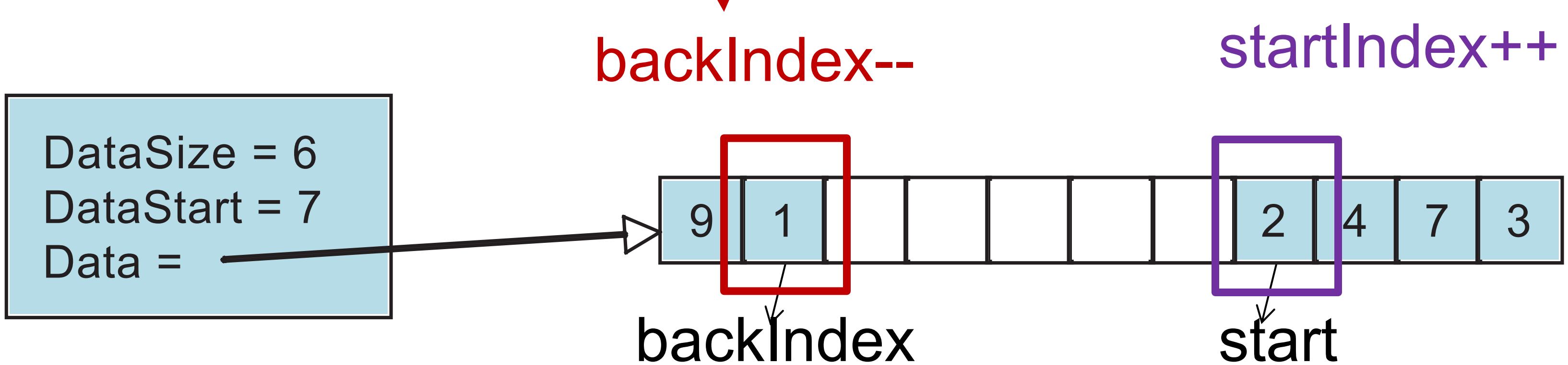
Adding/Removing for Deque

- **<u>Add front</u>: decrease the start index by 1**
- **<u>Add back</u>: increase size by 1**



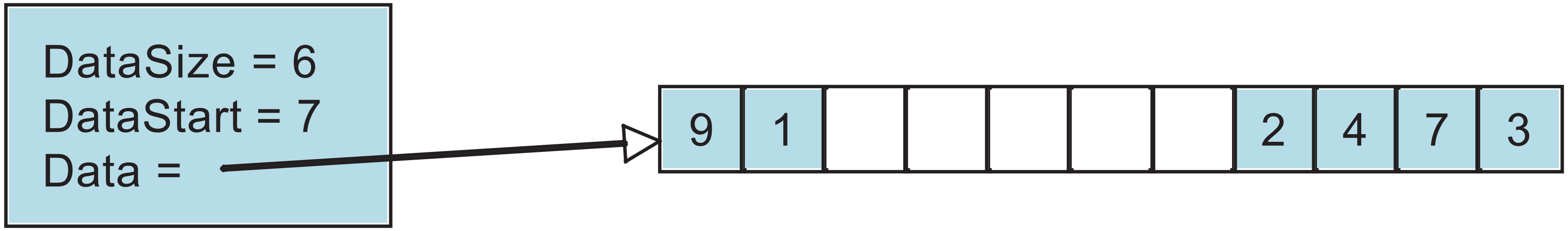
Adding/Removing for Deque

- Remove front: increase the start index by 1
- Remove back: decrease size by 1



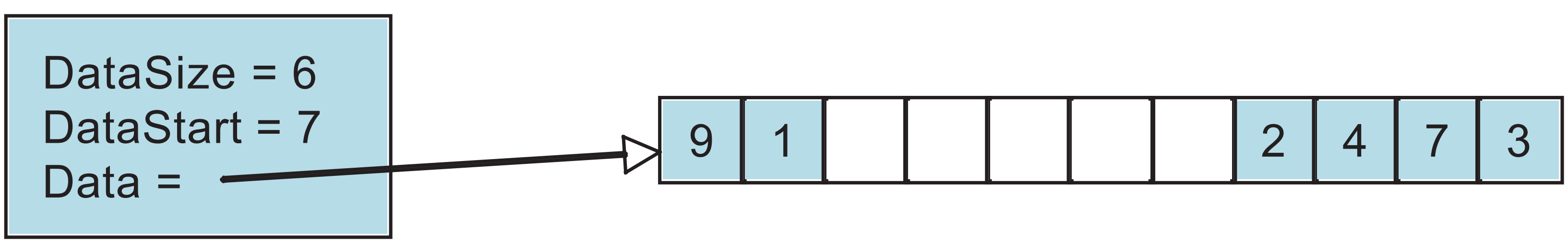
Adding/Removing for Deque

What if elements wrap around?



Wrapping: How to Compute New Index

- If Index < 0, then add capacity
- If Index > capacity, then subtract capacity
- If size == capacity, reallocate new buffer



Implementation

Deque Structure

```
struct deque {
    TYPE * data;
    int capacity;
    int size;
    int start;
};
```

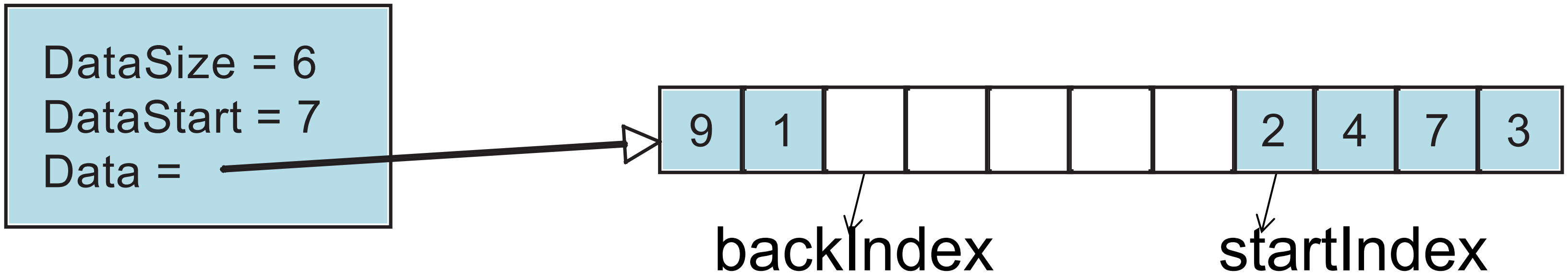
Keeping size vs Keeping pointer to end

- We compute the back index from the start index and size
- Why not keep the back index?
- OK, but need to compute size frequently

Wrapping: How to Compute Back Index

Use the **mod** operator:

```
backIndex = (start + size) % capacity;
```

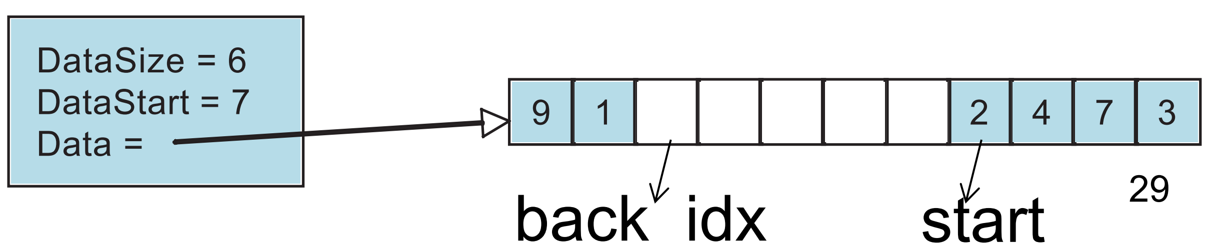


initDeque

```
void initDeque (struct deque *d, int initCapacity) {

   d->size = d->start = 0;/*initially, no data in Deque*/

   assert(initCapacity > 0);

   d->capacity = initCapacity;

   d->data =

         (TYPE *) malloc(initCapacity * sizeof(TYPE));

   assert(d->data != 0);

}
```

addBackDeque

```
void addBackDeque(struct deque *d, TYPE val) {

  int back_idx;

  if (d->size == d->capacity) _doubleCapDeque(d);

  /* Increment the back index */

  back_idx = (d->start + d->size) % d->capacity;

  d->data[back_idx] = val;

  d->size ++;

}
```



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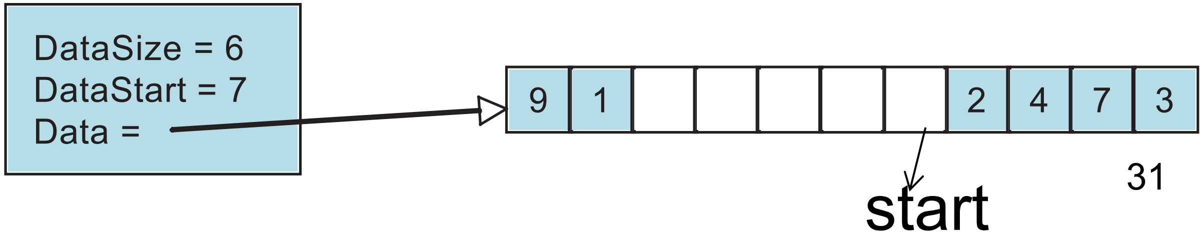
  d->size ++;
}
```

Complexity?

addFrontDeque

```
void addFrontDeque(struct deque *d, TYPE val) {
  if (d->size == d->capacity) _doubleCapDeque(d);
/* Decrement the front index */
  d->start--;
  if (d->start < 0) d->start += d->capacity;
  d->data[d->start] = val;
  d->size ++;
}
```



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  d->data[d->start] = val;
  d->size ++;
}
```

Complexity?

Worksheet 20

- Implement Dynamic Array Deque
- How do you
  - Add to front or back?
  - Return front? Return back?
  - Remove front? Remove back?

Queue as Deque

- Special case of Deque
- Add is O(1)
- Remove is O(1)