CS062

DATA STRUCTURES AND ADVANCED PROGRAMMING

11: Stacks and Queues

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she/her/hers

Lecture 11: Stacks and Queues

- Stacks
- Queues
- Applications
- Java Collections

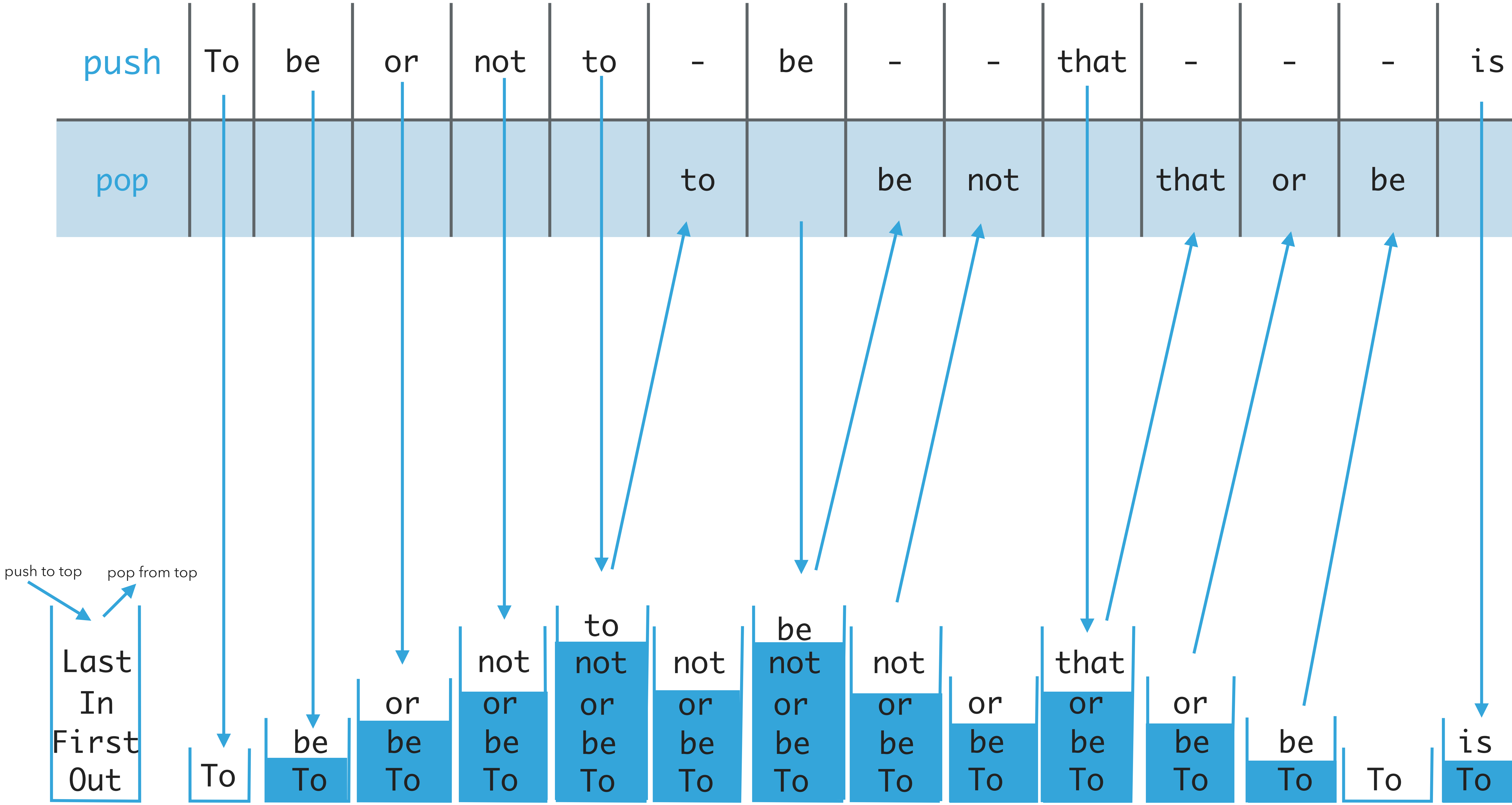
Some slides adopted from Algorithms 4th Edition and Oracle tutorials

Stacks

- Dynamic linear data structures.
- Elements are inserted and removed following the LIFO paradigm.
- LIFO: Last In, First Out.
  - Remove the most recent element.
- Similar to lists, there is a sequential nature to the data.

- Metaphor of cafeteria plate dispenser.
  - Want a plate? Pop the top plate.
  - Add a plate? Push it to make it the new top.
  - Want to see the top plate? Peek.
  - We want to make push and pop as time efficient as possible.

Example of stack operations



Implementing stacks with ArrayLists

- Where should the top go to make push and pop as efficient as possible?
- The end/rear represents the top of the stack.
- To push an element `add(E element)`.
  - Adds at the end. Amortized $O^+(1)$.
- To pop an element `remove()`.
  - Removes and returns the element from the end. Amortized $O^+(1)$.
- To peek `get(size()-1)`.
  - Retrieves the last element. $O(1)$.
- If the front/beginning were to represent the top of the stack, then:
  - Push, pop would be $O(n)$ and peek $O(1)$.

Implementing stacks with singly linked lists

- Where should the top go to make push and pop as efficient as possible?
- The *head* represents the top of the stack.
- To push an element `add(E element)`.
  - Adds at the head. $O(1)$.
- To pop an element `remove()`.
  - Removes and retrieves from the head. $O(1)$.
- To peek `get(0)`.
  - Retrieves the head. $O(1)$.
- If the last node were to represent the top of the stack, then:
  - Push, pop, peek would all be $O(n)$.

Implementing stacks with doubly linked lists

- Where should the top go to make push and pop as efficient as possible?
- The head represents the top of the stack.
- To push an element `addFirst(E element)`.
  - Adds at the head. $O(1)$.
- To pop an element `removeFirst()`.
  - Removes and retrieves from the head. $O(1)$.
- To peek `get(0)`.
  - Retrieves the head's element. $O(1)$.
- If the *tail* were to represent the top of the stack, we'd need to use `addLast(E element)`, `removeLast()`, and `get(size()-1)` to have $O(1)$ complexity.
- Guaranteed constant performance but memory overhead with pointers.

Implementation of stacks

- `Stack.java`: simple interface with `push`, `pop`, `peek`, `isEmpty`, and `size` methods.
- `ArrayListStack.java`: for implementation of stacks with ArrayLists. Must implement methods of `Stack` interface.
- `LinkedStack.java`: for implementation of stacks with singly linked lists. Must implement methods of `Stack` interface.

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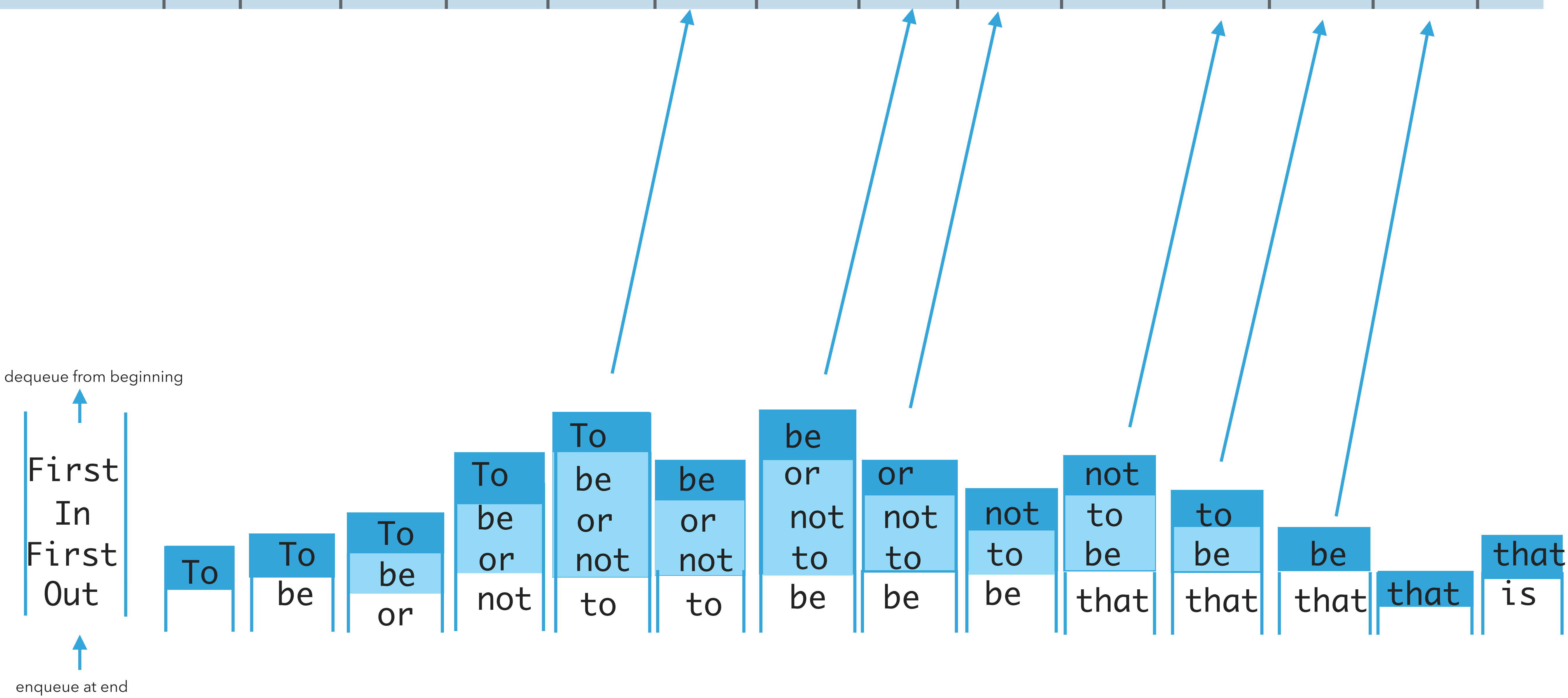
Queues

- Dynamic linear data structures.
- Elements are inserted and removed following the FIFO paradigm.
- FIFO: First In, First Out.
  - Remove the *least* recent element.
- Similar to lists, there is a sequential nature to the data.

- Metaphor of a line of people waiting to buy tickets.
- Just arrived? Enqueue person to the end of line.
- First to arrive? Dequeue person at the top of line.
- We want to make enqueue and dequeue as time efficient as possible.

Example of queue operations

enqueue	To	be	or	not	to	-	be	-	-	that	-	-	-	is
dequeue						To		be	or		not	to	be	



Implementing queue with ArrayLists

- Where should we enqueue and dequeue elements?
- To enqueue an element `add()` at the end of arrayList. Amortized $O^+(1)$.
- To dequeue an element `remove(0)`. $O(n)$.
- What if we add at the beginning and remove from end?
  - Now dequeue is cheap ($O^+(1)$) but enqueue becomes expensive ($O(n)$).

Implementing queue with singly linked list

- Where should we enqueue and dequeue elements?
  - To enqueue an element `add()` at the *head* of SLL ($O(1)$).
  - To dequeue an element `remove(size()-1)` ($O(n)$).
- What if we add at the end and remove from beginning?
  - Now dequeue is cheap ($O(1)$) but enqueue becomes expensive ($O(n)$).
- $O(1)$ for both if we have a tail pointer.
  - enqueue at the tail, dequeue from the head.
  - Simple modification in code, big gains!
  - Version that recommended textbook follows.

Implementing queue with doubly linked list

- Where should we enqueue and dequeue elements?
  - To enqueue an element `addLast()` at the tail of DLL ($O(1)$).
  - To dequeue an element `removeFirst()` ($O(1)$).
  - What if we add at the head and remove from tail?
    - Both are $O(1)$!
  - A lot of extra pointers! Also, in practice, "jumping" around the memory can increase significantly the running time.

Implementation of queues

- `Queue.java`: simple interface with `enqueue`, `dequeue`, `peek`, `isEmpty`, and `size` methods.
- `ArrayListQueue.java`: for implementation of queues with ArrayLists. Must implement methods of `Queue` interface.
- `LinkedQueue.java`: for implementation of queues with doubly linked lists. Must implement methods of `Queue` interface.

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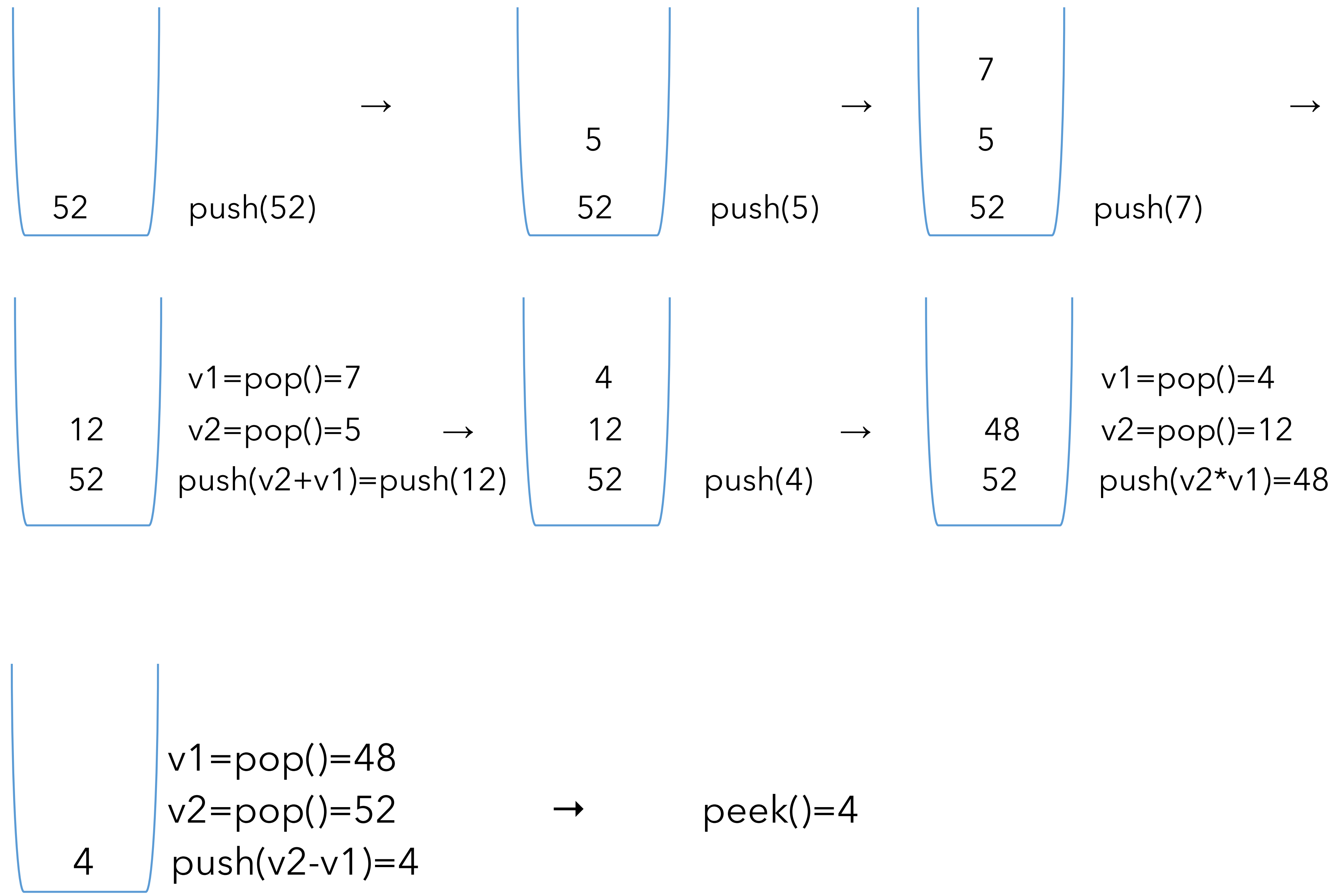
Stack applications

- Java Virtual Machine.
- Basic mechanisms in compilers, interpreters (see CS101).
- Back button in browser.
- Undo in word processor.
- Postfix expression evaluation.

Postfix expression evaluation example

Example: (52 - ((5 + 7) * 4) ⇒ 52 5 7 + 4 * -



Queue applications

- Spotify playlist.
- Data buffers (netflix, Hulu, etc.).
- Asynchronous data transfer (file I/O, sockets).
- Requests in shared resources (printers).
- Traffic analysis.
- Waiting times at calling center.

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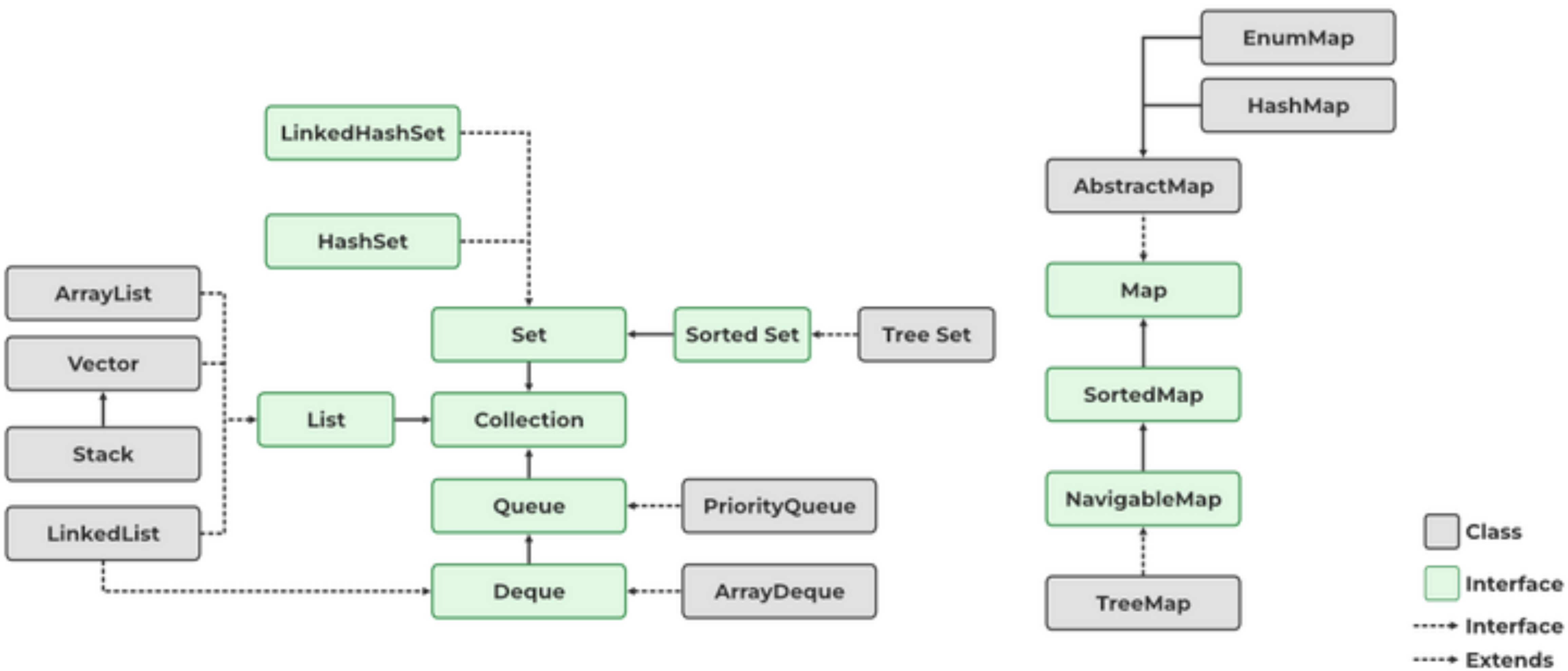
The Java Collections Framework



Deque in Java Collections

- Do not use `Stack`. Deprecated class.
- `Queue` is an interface…
- It's recommended to use the `Deque` interface instead.
    - Double-ended queue (can add and remove from either end).

```
java.util.Deque;

public interface Deque<E> extends Queue<E>
```

- You can choose between `LinkedList` and `ArrayDeque` implementations.
    - `Deque deque = new ArrayDeque(); //preferable`

https://docs.oracle.com/javase/8/docs/api/java/util/Deque.html

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Readings:

- Oracle's guides:
  - Collections: https://docs.oracle.com/javase/tutorial/collections/intro/index.html
  - Deque: https://docs.oracle.com/javase/8/docs/api/java/util/Deque.html
  - ArrayList: https://docs.oracle.com/javase/8/docs/api/java/util/ArrayList.html
- Recommended Textbook:
  - Chapter 1.3 (Page 126–157)
- Recommended Textbook Website:
  - Stacks and Queues: https://algs4.cs.princeton.edu/13stacks/

Code

- Lecture 11 code

Practice Problems:

- 1.3.2–1.3.8, 1.3.32–1.3.33