COMP 2402 Class Notes

Java Collections Framework (JCF)

The Java Collections Framework (JCF) is a unified architecture for representing and manipulating collections.

A collection — sometimes called a container — is simply an object that groups multiple elements into a single unit. Collections are used to store, retrieve, manipulate, and communicate aggregate data. Typically, they represent data items that form a natural group, such as a poker hand (a collection of cards), a mail folder (a collection of letters), or a telephone directory (a mapping of names to phone numbers). If you have used the Java programming language — or just about any other programming language — you are already familiar with collections.

In order to use the JCF you can import it like this.

```
import java.util.*
```

Sorting

This is how to sort strings based on length by using anonymous object [**Comparator**].

```
Collections.sort(list, new Comparator<String>() {
    public int compare(String x, String y) {
        return x.length() - y.length();
    }
});

// or you can use lambda function
list.sort( (String o1, String o2) -> o1.compareTo(o2)
```

```
);

// if you want to sort by length and also
alphabetically
Collections.sort(list,new Comparator<String>() {
    public int compare(String x, String y) {
        // if not same length, use length
        if(x.length() != y.length()) {
            return x.length() - y.length();
        }
        // else compare as strings
        return x.compareTo(y);
    }
});
```

The **compare(x,y)** method works by moving an element left if the **compare(x,y)** method returns a negative integer, and moves the element right if the **compare(x,y)** returns a positive integer. [difference between x and y]

```
(-) x < y
(0) x = y
(+) x > y
```

Maps [Hashmap]

Also known as dictionaries in Swift or C#...

- Cannot have duplicate entries

```
Map<String, Integer> map = new HashMap<>();
map.put("Java", 6);
map.put("Swift", 10);
map.put("C#", 7);
map.put("Ruby", 9);
```

```
// this will print out every value in the map [foreach]
for(String str : map.keySet()) {
    System.out.println(str + " : " + map.get(str))
}

map.get(key); // fast operation, returns null if no key
found
```

List

Continuing from previous example...

Map.Entry is just a key-value pair

```
List<Map.Entry<String,Integer>> entryList = new
ArrayList<>();
entryList.addAll(map.entrySet); // set containing all
the elements

for(Map.Entry<String,Integer> entry : entrylist) {
    System.out.println(entry.getKey() + " : " +
entry.getValue() );
}
```

Deque [ArrayDeque]

Fast for reading/writing at *start* or *end* of list. Basically just a flexible stack/queue.

```
Deque<String> dq = new ArrayDeque<>();
dq.addFirst("second");
dq.addFirst("first");
dq.addLast("penultimate");
dq.addLast("last");
```

Priority Queue

Essentially: uses a heap instead of a tree, in order to keep a certain one on top. So first element is 'sorted' and then rest is unsorted.

Not good for sorting, or random access.

```
Queue<String> pq = new PriorityQueue<>();
pq.addAll(list);

System.out.println(pq.remove());    // remove smallest
element
```

If alphabetical, one that starts with 'a' will be removed. After first element, the queue is not sorted. Removing one will promote next smallest to the top

Asymptotic Notation [Big O]

Used to analyze complexity of algorithms, to find faster, or which ones requires more space.

Comparing data structures

- Time
- Space
- Correctivenes

Growth rates proportioanl to n

- If input doubles in size, how much will runtime increase?

Runtime as a count of primative operation

- This is machine independent

- Proportional to exact runtimess

```
for(int i = 0; i < n; i++) {
    arr[i] = i;
}
```

Runtime:

- **1**: assignment [int i = 0]
- **n+1**: comparisons [i < n]
- **n**: increments [i++]
- **n**: array offset calculations [arr[i]]
- **n**: n indirect assignments [arr[i] = i]

Definition of Big O

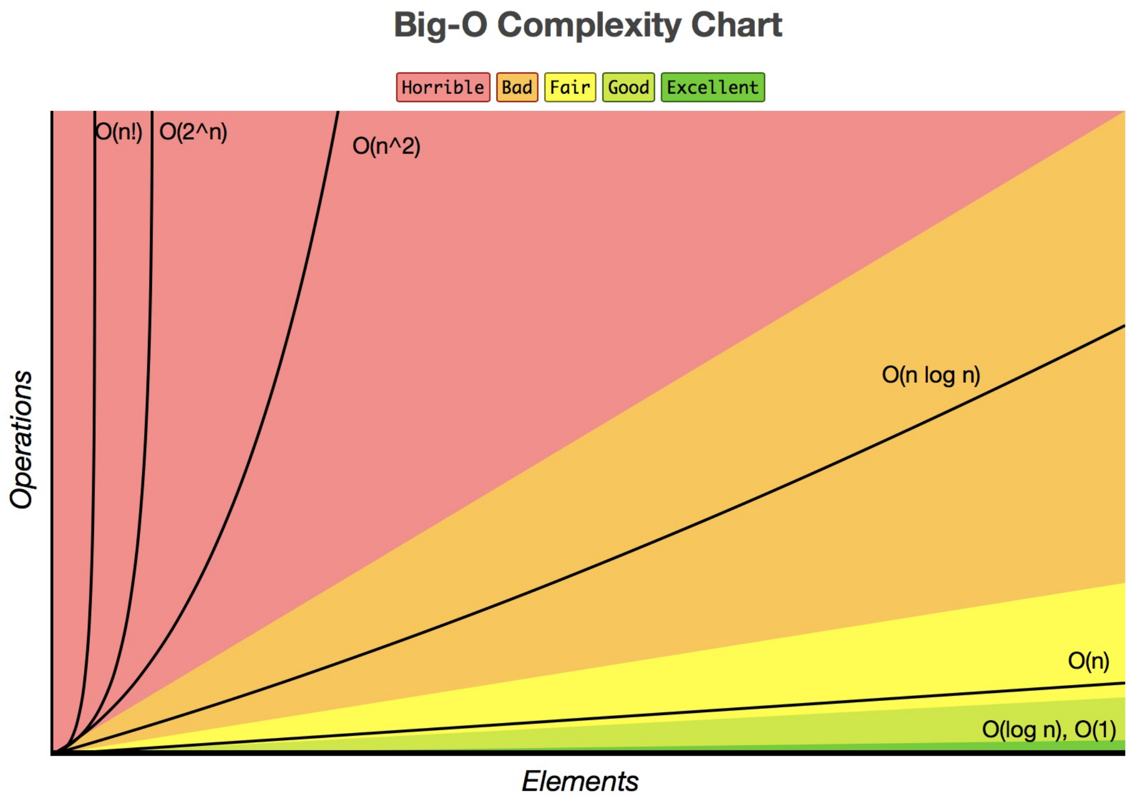
After a certain point, g(x) will grow as fast [or faster] than f(x)

- g(x) is the upper limit to f(x)

$O(g(n)) \forall (f(n) < c \bullet g(n))$

Orders of growth

Complexity	Name
O(1)	Constant
O(log n)	Logarithmic
O(n)	Linear
O(n log n)	Quasilinear
O(n^2)	Quasilinear
O(2^n)	Exponential
O(n!)	Factorial



Tips

- Only largest values matter
- Drop all coefficient
- Log bases are all equivalent

Example

```
public class BigO {
    public static void main() {
        String str = "";
        int n = 100;    // O(1)

        for(int i = 0; ,< n; i++) {     // O(n)
            str += "x";     // O(1) but n times
        }

        for(int i = 0; i < n; i+=2) {    // n/2 times -
> O(n)
            str += "y"      // O(1)
```

```
        }

        // this is roughly the same as if n was n/2
with O(n)
        for(int i = 0; i < n; i*=2) {    // O(log n)
            str += "y"       // O(1)
        }
    }
}
```

Array-based Data Structures

ArrayStack

- Implements **List** interface with an array
- Similar to ArrayList
- Efficient only for stack opertations
- superceded by ArrayDeque
- **get(), set() in O(1 + n-i)**
    - good for accessing the back

Stacks vs List

Stack	List
push(x)	add(n,x)
pop()	remove(n-1)
size()	size()
peek(x)	get(n-1)

List Interface

- get(i) / set(i,x)
    - Access element i, and return/replace it
- size()

    - number of items in list
- add(i,x)
    - insert new item x at position i
- remove(i)
    - remove the element from position i

dereferencing: getting the address of a data item

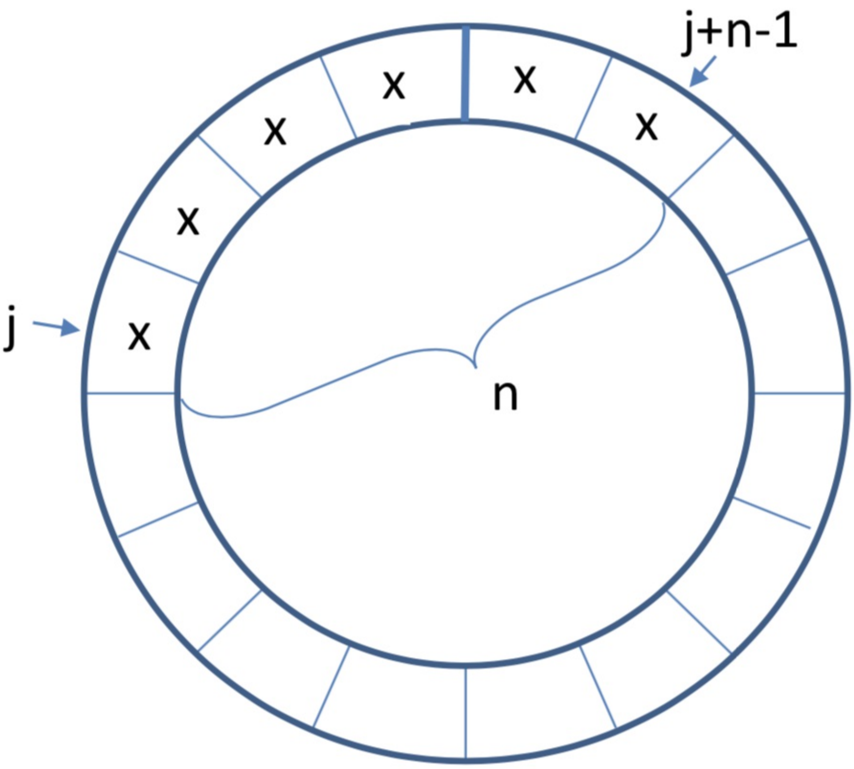
Amortized Cost

When an algorithm has processes that may be much longer but usually is quick, so you take the average. [roughly]

e.g. resizing an an array when adding/removing

ArrayQueue & ArrayDeque

Allow for efficient access at front and backs.



ArrayQueue

- Implements **Queue** and **List** interfaces with an array

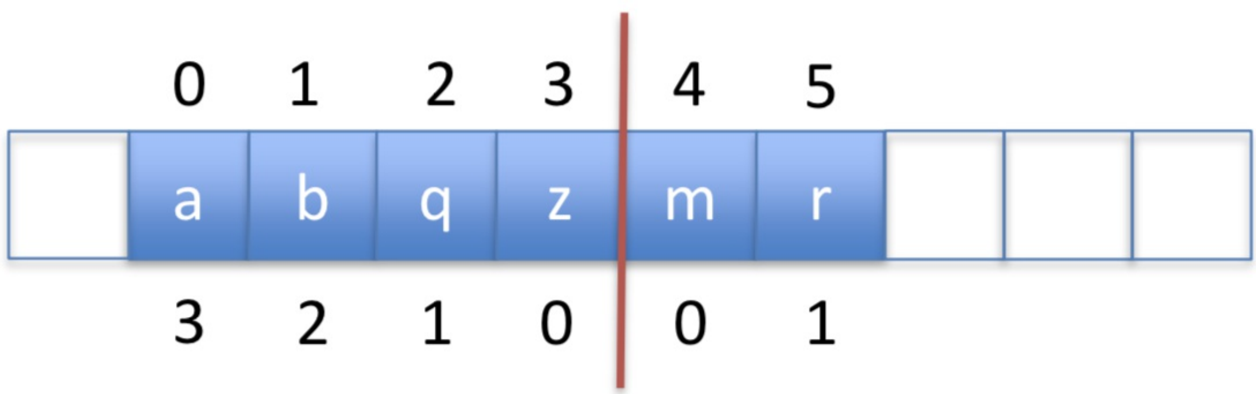
- Cyclic array, (n: number of elements, j: 'index' of last element)
- **add(), remove() in O(1)**
    - quick to access front or back
    - cannot access anywhere else
- **resize is O(n)**

ArrayDeque

- Implements **List** interface with an array
- **get(), set() in O(1)**
- **add(), remove () in O(1 + min(i, n-i))**
    - quick to access front or back
    - not so quick to access middle
- **resize is O(n)**

DualArrayDeque

- Implements **List** interface
- Uses two **ArrayStacks** front-to-front
- Since arrays are quick to add to the end, this makes front and back operations fast
- May be rebalanced if one array is much larger than the other
- Use Potential Function to decide when to rebalance
- **get(), set() in O(1)**
- **add(), remove() in O(1 + min(i, n-i))**
    - quick to access front or back, but not middle



Potential Function

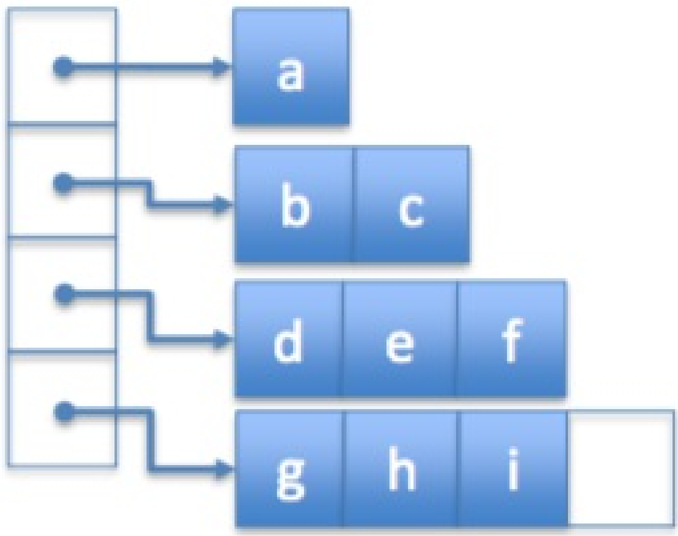
Define a potential function for the data structure to be the absolute difference of the sizes of the two stacks

P = | front_array.size - back_array.size |

- Adding or removing an element can only increase/decrease 1 to this function

RootishArrayStack

- Implements the **List** interface using multiple backing arrays
- Reduces 'wasted space' [unused space]
- At most: *sqrt(n)* unused array locations
- Good for space efficiency
- **get(), set() in O(1)**
- **add(), remove() in O(1 + n-i)**
    - quick to access the back

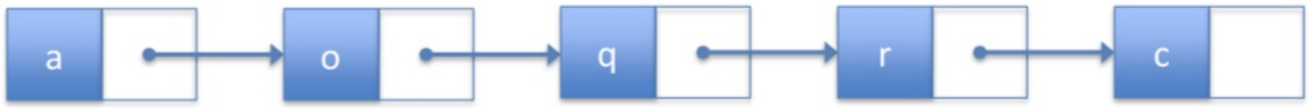


Linked Lists

- Recursive data structure made up of nodes
- Pointers to head and tail, and each node points to the next node
- Efficient add/remove but slow read/write

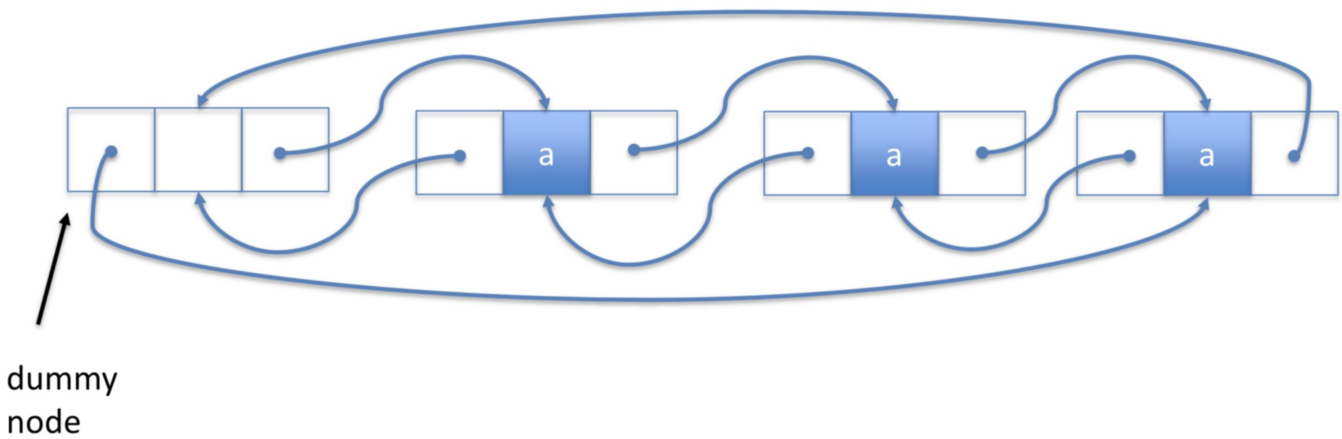
SLList [Singly-Linked List]

- Implements the **Stack** and **Queue** interfaces
- **push(), pop() in O(1)**
- **add(), remove() in O(1)**



DSList [Doubly-Linked List]

- Forward and backwards pointers at each node
- Implements the **List** interfaces
- **get(), set() in O(1 + min(i, n−i))**
- **add(), remove() in O(1 + min(i, n−i))**



SELList [Space-Efficient Linked List]

- Like a doubly-linked list, but uses block size *b*
- Is an **ArrayDeque**
- Implements the **List** interfaces
- **get(), set() in O(1 + min(i, n−i)/*b*)**
- **add(), remove() in O(1 + min(i, n−i)/*b*)**