Queues

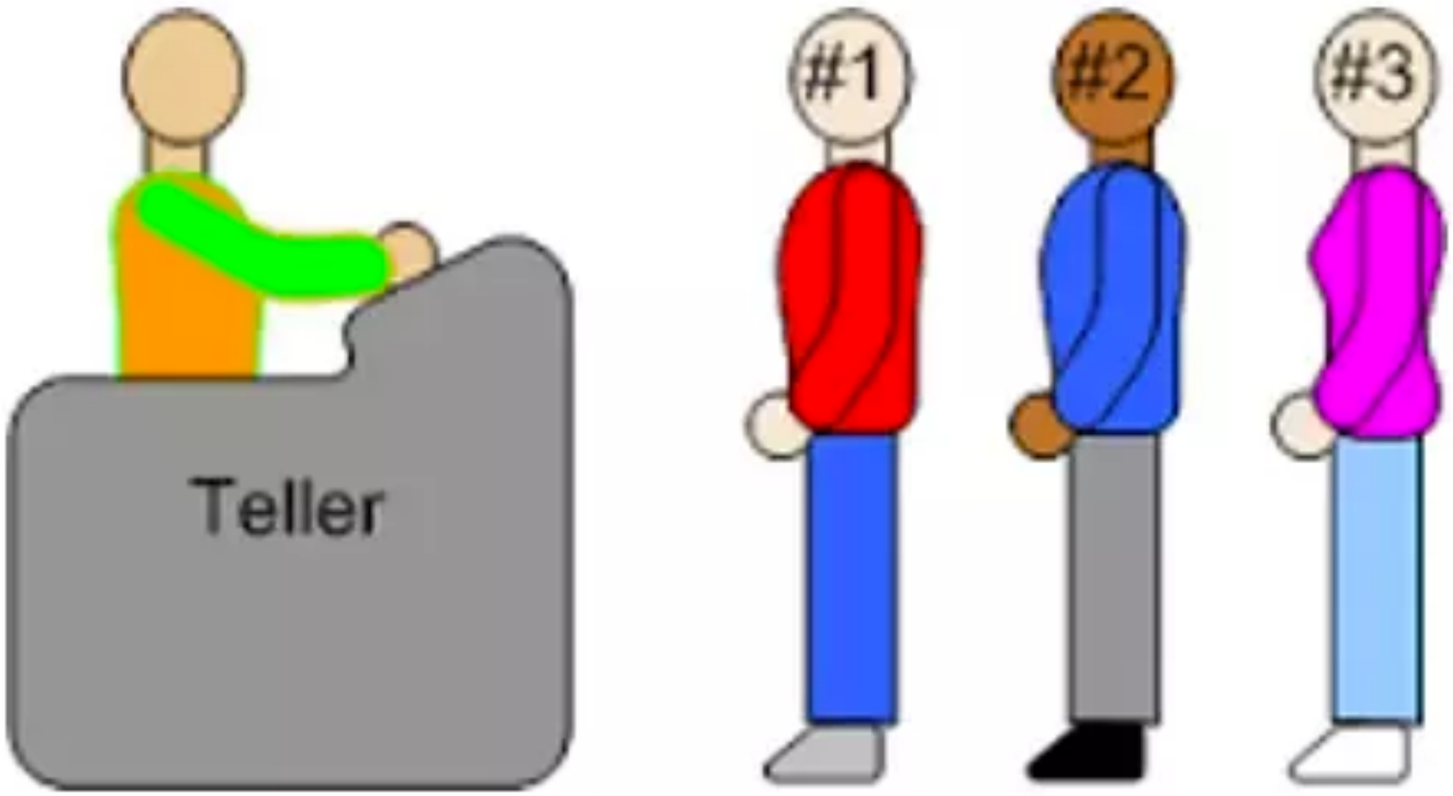
More with Comparable

Priority Queues

Queueing Theory

Agner Krarup Erlang

Queues



`Queue` Interface

- `null` is returned from `getFront()` and `dequeue()` when queue is empty
- return false from offer when cannot add to queue.

```
public interface QueueInterface<E> {
   int size();
   boolean isEmpty();
   E getFront();     // peek
   boolean enqueue(E e);
   E dequeue();
   void clear();
}
```

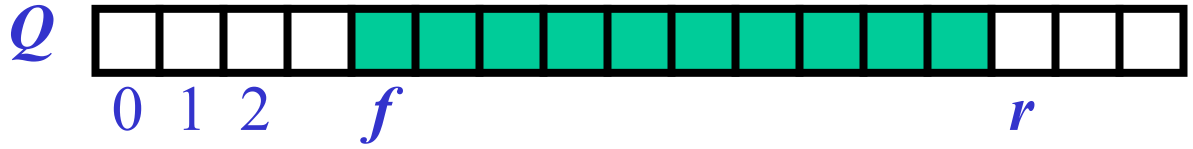
Example

Operation	output	Queue Contents
enqueue(5)	TRUE	{5}
enqueue(3)	TRUE	{5, 3}
dequeue()	5	{3}
enqueue(7)	TRUE	{3, 7}
dequeue()	3	{7}
getFront()	7	{7}
dequeue()	7	{}
dequeue()	null	{}

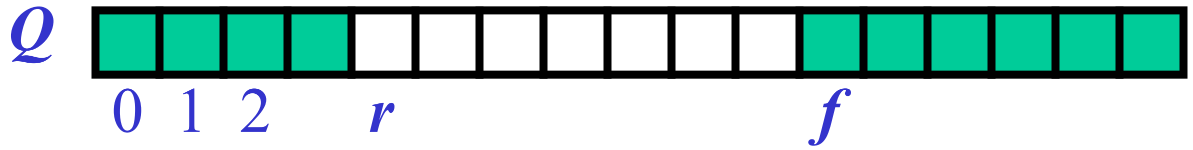
Array-based Queue

- An array of size `n` in a circular fashion
  - `frontLoc`: index of the front element
    - where objects are read
  - `count`: number of stored elements
  - `rearLoc`: index of rear element
    - where objects are added

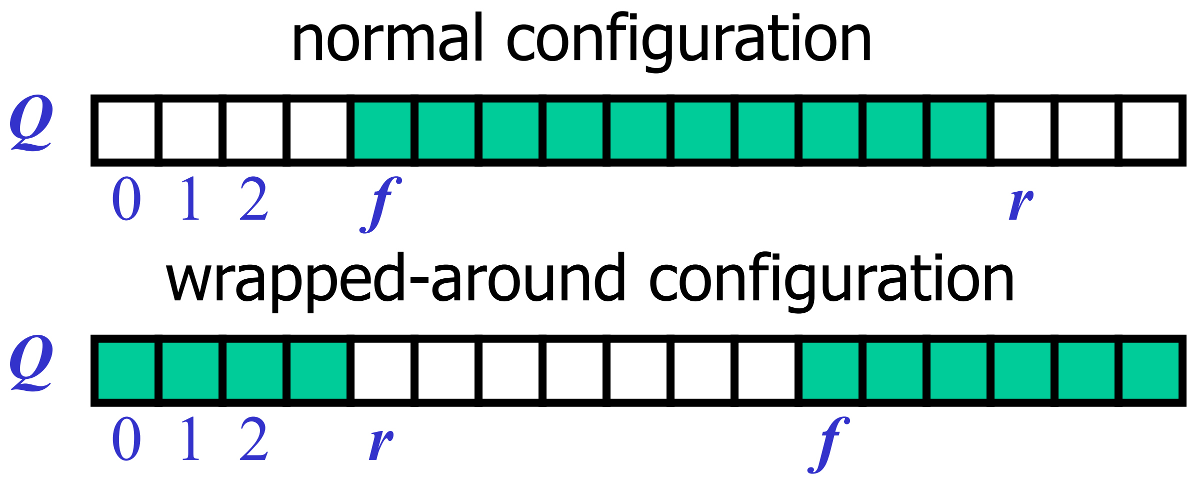
normal configuration



wrapped-around configuration



Circular Array and Queue



Performance and Limitations for array-based Queue

- Performance
  - let n be the number of objects in the queue
  - The space used is $O(n)$
  - Each operation runs in time $O(1)$
- Limitations
  - Max size is limited and can not be changed
  - Adding to a full queue returns false (enqueue method)

Start of Queue Implementation

```
public class ArrayQueue<Q> implements QueueInterface<Q> {
    private static final int DEFAULT_CAPACITY = 42;
    private Q[] backingArray;
    private int count;
    private int frontLoc;

    public ArrayQueue() {
         this(DEFAULT_CAPACITY);
    public ArrayQueue(int qSize) {
        count = 0;
        frontLoc = 0;
        backingArray = (Q[]) new Object[qSize];
    }
    public int size() {
        return count;
    }
```

Java Documentation
Queue offer Method (enqueue)

enqueue

`boolean ~~offer~~(E e)`

Inserts the specified element into this queue if it is possible to do so immediately without violating capacity restrictions. When using a capacity-restricted queue, this method is generally preferable to `add(E)`, which can fail to insert an element only by throwing an exception.

Parameters:

`e` - the element to add

Returns:

`true` if the element was added to this queue, else `false`

Write enqueue and dequeue

```
public class ArrayQueue<Q> implements QueueInterface<Q> {
    private static final int CAPACITY = 42;
    private Q[] backingArray;
    private int count;
    private int frontLoc;

    boolean enqueue(Q e);  // add item to queue  // write with class
    Q dequeue(); // remove item from queue  // write in groups
```

S_{orted}A_{rray}L_{ist}

```
public class Sal<C> {
```

- Problem
    - how to guarantee that the Generic class C has an ordering …
        - Homework 4 convert to string and compare those strings
        - That method is less than optimal .... Why?
- It would be better to require that items have an ordering
    - or at least that items know ordering with respect to each other.
- In Java — require the Comparable interface

```
    public class Sal<C extends Comparable<C>> {
```

Comparable Interface

- Part of Java language
- Idea, give a way for classes to define a total ordering of instances
- Java classes that implement:
  - String
  - All descendants of Number
  - Lots of others

The Comparable Interface

- `public interface` **`Comparable<T>`**
  This interface imposes a total ordering on the objects of each class that implements it. This ordering is referred
  as the class's *natural ordering*, and the class's `compareTo` method is referred to as its *natural comparison method*.Lists (and arrays) of objects that implement this interface can be sorted automatically by `Collections.sort` (and `Arrays.sort`). Objects that implement this interface can be used as keys in a sorted map or as elements in a sorted set, without the need to specify a comparator.
  The natural ordering for a class `C` is said to be *consistent with equals* if and only if `e1.compareTo(e2) == 0`
  the same boolean value as `e1.equals(e2)` for every `e1` and `e2` of class `C`. Note that `null` is not an instance o
  any class, and `e.compareTo(null)` should throw a `NullPointerException` even though `e.equals(null)` returns `false`.
  It is strongly recommended (though not required) that natural orderings be consistent with equals. This is so because sorted sets (and sorted maps) without explicit comparators behave "strangely" when they are used wit
  elements (or keys) whose natural ordering is inconsistent with equals. In particular, such a sorted set (or sorte
  map) violates the general contract for set (or map), which is defined in terms of the `equals` method.
  For example, if one adds two keys `a` and `b` such that `(!a.equals(b) && a.compareTo(b) == 0)` to a sor
  set that does not use an explicit comparator, the second `add` operation returns false (and the size of the sorted
  does not increase) because `a` and `b` are equivalent from the sorted set's perspective.
  Virtually all Java core classes that implement `Comparable` have natural orderings that are consistent with equ
  One exception is `java.math.BigDecimal`, whose natural ordering equates `BigDecimal` objects with equal values and different precisions (such as 4.0 and 4.00).
  For the mathematically inclined, the *relation* that defines the natural ordering on a given class C is:

  ```
        {(x, y) such that x.compareTo(y) <= 0}.
  ```
-

Comparable interface (shortened)

`int compareTo(T o)`
Compares this object with the specified object for order. Returns a negative integer, zero, or a positive integer as this object is less than, equal to, or greater than the specified object.
The implementor must ensure `sgn(x.compareTo(y)) == -sgn(y.compareTo(x))` for all `x` and `y`. (This implies that `x.compareTo(y)` must throw an exception iff `y.compareTo(x)` throws an exception.)

The implementor must also ensure that the relation is transitive: `(x.compareTo(y)>0 && y.compareTo(z)>0)` implies `x.compareTo(z)>0`.

Finally, the implementor must ensure that `x.compareTo(y)==0` implies that `sgn(x.compareTo(z)) == sgn(y.compareTo(z))`, for all `z`.

It is strongly recommended, but *not* strictly required that `(x.compareTo(y)==0) == (x.equals(y))`. Generally speaking, any class that implements the `Comparable` interface and violates this condition should clearly indicate this fact. The recommended language is "Note: this class has a natural ordering that is inconsistent with equals."

In the foregoing description, the notation `sgn(`*expression*`)` designates the mathematical *signum* function, which is defined to return one of `-1`, `0`, or `1` according to whether the value of *expression* is negative, zero or positive.

Parameters:
`o - the object to be compared.`
Returns:
`a negative integer, zero, or a positive integer as this object is less than, equal to, or greater than the specified object.`

Comparable Interface (even shorter)

```
public interface Comparable<T> {
   int compareTo(T o);
}
```

- return 0 if they are equal
- return <0 if caller is less than compared
- return >0 if caller greater than compared
  - Integer v3 = Integer.valueOf(3).
  - v3.compareTo(4) ==> -1
  - "DQ".compareTo("DR") ==> 3

Comparable Rabbit

```
public class Rabbit implements Comparable<Rabbit> {
    private final int iD;
    private final String nickname;
    public Rabbit(int id, String nn) {
        this.iD = id;
        this.nickname = nn==null ? makeName() : nn;
    }

// implement Comparable interface so that rabbits
// are sorted based on their iD.
```

Priority Queue

- Rather than FiFo, remove items according to their priority
  - Implement:
    - same methods as queue(?)
      - Others needed?

```
public class PriorityQueue<B extends Comparable<B>>
    extends ArrayList<B>
    implements QueueInterface<B>

public class PriorityQueueSAL<P extends Comparable<P>>
    extends SALextending<P>
    implements QueueInterface<P>
```

PriorityQueue

- Implementation a trivial extension on SAL!!!
- Small difference
  - Usually PQ are on K,V pairs where
    - K — the priority
    - V — the item in the queue
- Q: Does K,V pair matter?